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WATER QUALITY CONSIDERATIONS FOR THE METAL MINING INDUSTRY IN THE PACIFIC NORTHWEST

Jack E. Sceva

Environmental Protection Agency
Seattle, Washington

1973

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Prepared by

Jack E. Sceva

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INTRODUCTION

The mining industry is confronted at almost every turn by citizens, organizations and agencies that are concerned about the protection of the environment. This opposition is a result of the historic lack of concern for our land and water resources by many early mine operators. In some areas, land, streams and lakes have been irreparably damaged by early-day mining. Thousands of acres in Oregon and Idaho have been left in ruin by open pit and dredge mining operations. Some valley floors in Northern Idaho have become barren wastelands from the deposition of mine and mill wastes. The Coeur d'Alene River and some of its tributaries have been degraded by mining operations to the point that they are now unsuitable for many purposes. Mining has also resulted in the creation of stream barriers and the destruction of fish habitats.

In response to these outcries, many mining companies have made great efforts to reduce their environmental impact and erase the stigma created by the early day mine operators. The scars on our land and damaged water resources make the creation of a new image for the mining industry very difficult. Some mining companies have demonstrated their concern by constructing tailings ponds to remove the suspended material from their waste streams, recycled waste water to reduce the quantity of their waste, reclaimed and revegetated damaged lands, eliminated stream barriers, and initiated erosion prevention programs. Unfortunately, the general public is often unaware of the efforts by mining companies to reduce and control the impact of their operations on the natural environment.

It is particularly important to understand that mining is essential to the activities of man, and as highgrade ores are depleted, opening new mines and development of lower grade ore reserves is inevitable. However, it is not inevitable that mining methods and procedures for abatement of pollution will remain as they have for the last 100 years. Environmental protection has become so important to civilized man that it plays a major role in the feasibility, design, construction and operation of mining projects. Unfortunately, nature has not always deposited minerals at locations best suited to provide environmental protection, and extraordinary precautions may be required in some areas to minimize the impact of mining on the environment.

Major conflicts generally occur when mining is proposed in a watershed that is used as a source of public water supplies or where the streams are used for fish migration, spawning and habitat. Conflicts in land use also occur where mining will jeopardize recreation and the preservation of wildlife.

The purpose of this report is to describe the principal causes of water pollution at both active and abandoned mines and to provide suggestions and recommendations for minimizing the effects of mining on water quality. Part 1 of the report discusses problems related to the exploration and development of a mineral deposit, the mining of the ore and control of mine drainage, the milling of ore, and the construction and operation of tailings ponds. The water pollution problems associated with abandoned mines are discussed in Part 2 and items relating to the construction of mine roads are given in Part 3.

This part also presents some practices that would prevent or minimize similar water pollution problems from developing in the future. In no case should these recommended practices be construed as authorizing any violation of existing local, state or Federal laws and regulations that would relate to the mining operations. It is the mining companies responsibility to be aware of and to comply with these laws and regulations.

The 1972 Federal Water Pollution Control Act (P.L. 92-500) contains many provisions that relate directly with mining operations. It establishes a national goal of eliminating the discharge of pollutants into the waters of the United States by 1985. Interim goals call for the application of best practicable control technology by 1977 and the best available technology by 1983.

One of the more important provisions (Sec. 402) establishes a "National Pollutant Discharge Elimination System" through a waste discharge permit system. Every discharge to surface water will require a NPDES permit that sets forth effluent limitations and other control provisions. Appendix A gives the interim effluent guidance for mining and milling permits. Guidelines for effluent limitations will be forthcoming in the near future (Sec. 304).

The FWPCA (Sec. 303) also requires the states to establish water quality standards for all surface waters. These standards describe water quality conditions that are acceptable to the states and Federal government. The standards for turbidity, suspended solids and heavy metals will have a direct effect on mining operations in the Pacific Northwest.

Other provisions relate to the control of toxic materials (Sec. 307), mine water pollution control demonstrations (Sec. 107) and a preparation of guidelines and methods of control of nonpoint sources of pollution from mining activities (Sec. 304). The toxic materials list includes mercury, cadmium and cyanide.

PART 1 - WATER QUALITY CONSIDERATIONS AT ACTIVE MINES

Exploration and Development

After a mineral deposit has been located, specific information about the extent and grade of the deposit is required to evaluate the discovery and to formulate mining plans. Water pollution problems in this phase of mining are related to (1) access; (2) exploration involving drilling, trenching, and tunneling or sinking shafts; and (3) support facilities for both workers and equipment.

To perform this type of exploration, heavy equipment and support facilities are required at the site. The transportation of this equipment is often the beginning of the water pollution problem since access roads to an exploration site are not always constructed with adequate consideration for environmental protection. Access across Federal land requires a special use permit for road construction from the appropriate land management agency. These permits usually specify how and where the roads are to be constructed. These same requirements do not apply to access roads constructed across private land or access roads on the mining claim being examined. Too often the "cheapest" type of access is utilized, and this access may also have the greatest environmental costs. Roads crossing streams with inadequate culverts may lead to road washouts; improper road location or cuts may initiate land slumping; and erosion that may be very difficult if not impossible to control.

Recent exploration work in Idaho was supplied entirely by helicopter air lift. This type of access provides a minimum of

environmental damage and may prove cheaper than constructing an environmentally safe road to an ore deposit being evaluated. It has also been suggested that oversnow vehicles be utilized to supply exploration sites so as to eliminate the need for road construction.

Several years ago the Federal Water Pollution Control Administration (Environmental Protection Agency) developed guidelines for logging practices including the construction of logging roads. As logging roads are not materially different from mine access roads, the guidelines have been modified for mine access roads and are presented in Part 3.

It has been the general practice to dump excavated material from the construction of pits, trenches and cuts over the nearest hillside and to abandon the excavations after the desired information has been collected. These excavations often lead to accelerated erosion, the waste dumps may block or dam water courses, and the excavations can leave lasting scars on the topography. If these excavations are constructed on a mining claim on Federal land, they are a direct concern of the government as the mining company may abandon the claim and the scars, erosion and environmental damage then reverts to the Federal government and becomes a public liability.

From an environmental standpoint, it would be desirable to minimize the land surface disturbed by backhoes and bulldozers and to fill or restore all test excavations and revegetate the areas prior to site abandonment. If this practice is planned in advance, rock materials can be stockpiled during excavation and the task of restoration can be minimized.

Drill holes are often used in mineral exploration. These may range from small diameter diamond drill holes to large diameter test holes. If confined water is encountered, these wells may flow at the surface and discharge mineralized water to streams (see Appendix C6). The wells are often plugged with drilling mud or drill cuttings, but these materials do not normally form perfect seals. The confined water may break through to the ground surface after the site is abandoned and become a source of water pollution. With little effort, a mining company can adequately plug its test wells with cement grout which generally forms a tight and lasting seal.

In large bulk sampling tests, long tunnels, exploratory drifts, or deep shafts may be constructed. These openings are essentially mines, and pollution from mine drainage can occur. Mine drainage is a much more difficult problem to control than is filling a trench or sealing a drill hole. If a particular vein or joint is the source of mineralized water in the tunnel or shaft, it may be feasible to grout the joints or otherwise seal off the water-bearing zone to reduce the flow. This requirement would be similar to requiring an oil company to plug an oil test well to prevent salt water from polluting an overlying aquifer.

Mines are not greatly different from large wells in that they can drain or dewater the overlying or adjacent rock materials. The overlying or adjacent rocks may contain substantial quantities of pyrite (FeS_2), a common sulfide mineral that is often associated with sulfide ore minerals. Water containing oxygen can percolate

from the surface down through the dewatered rocks and react with the pyrite to form sulfuric acid. The acid water then seeps into the mine workings and discharges out the portal as acid mine drainage. The quality of water draining a mineralized area will generally be substantially more acidic after the construction of tunnels and drifts because of the resulting change in the ground water flow pattern (see Appendix C12).

The support facilities for an exploration project can also be sources of water pollution. Sewage may drain into a stream, garbage may be dumped in an area where it will be washed into a stream or petroleum products may leak or be spilled into a stream. If these problems are considered in the location and design of the camp, shop, fuel storage or other facilities, substantial environmental protection can often be obtained for little additional cost.

Mining Operations

Large metal mining operations in the Pacific Northwest are relatively few in number. In Oregon, there is the Nickel Mountain Mine near Riddle. The Knob Hill Mine at Republic and the Pend Oreille Mine at Metaline Falls are located in Washington. In Idaho, there are the Lucky Friday Mine at Mullan, the Star-Morning Mine at Burke, the Galena and Dayrock Mines near Wallace, the Sunshine, Cresent and Bunker Hill Mines near Kellogg and the Clayton Silver Mine near Clayton. All of these except the Nickel Mountain Mine are underground operations. There are a few smaller operating mines and numerous active mining claims on which assessment work is performed. Water

pollution problems at active mining operations are related to (1) mine drainage; (2) support facilities for both workers and equipment; and (3) erosion, leaching and runoff from above ground facilities.

In underground mining there is always a certain amount of waste material that must be removed from the mine besides the waste rock. These wastes include seepage water which is often highly mineralized, industrial waste water used for dust control or drilling, drainage from sand filling operations, sanitary wastes, oil and grease, paper, wood and various containers.

Mines are designed and constructed so that liquid wastes and mine water will drain into some centrally located area where they are allowed to settle in an excavated sump. The supernatant in the sump is pumped to the surface for disposal. In some of the deeper mines, drainage from the lower workings may be pumped to an intermediate level sump and pumping facility to overcome extremely high pumping pressures and to eliminate the necessity of pumping all of the mine drainage from the bottom of the mine.

An important purpose of the sumps or settling facilities in the mine is to protect the pumps. Iron precipitates and sand in mine drainage are very hard on pumping equipment; for economic reasons it is good practice to separate these materials from the mine drainage prior to pumping. At the Bunker Hill Mine, the sediment from the settling sumps is occasionally removed and hoisted to the adit level. It is then flushed out of the mine with the mine drainage and discharged to the tailings pond. The sediment removed from settling tanks in mines can be serious sources of water pollution if dumped or discharged into a stream.

One mine operator reported they tried to treat drainage with lime prior to pumping the waste to the adit level. This operation did not prove very successful due to the difficult and costly task of transporting the chemicals to the underground waste storage tanks. This type of underground treatment would also add to the sludge removal problem since a larger volume of sludge would be produced.

Mine water often consists of both juvenile water and meteoric water. Juvenile water is new water that is produced or released by chemical reactions deep in the earth. This water is usually highly mineralized and in some cases may be similar to the solutions that deposited the ore minerals being mined. Meteoric water is derived from the atmosphere and can gain entry to the mine by percolating down through the overlying rock materials or through abandoned workings. Mine drainage of meteoric origin may have a marked variation in seasonal flow due to seasonal changes in precipitation and runoff. The rapidity of changes in the amount of mine drainage to changes in precipitation or runoff can be an indicator of the accessibility of surface water to a mine. The quicker the response, the greater the accessibility. In some cases, mine drainage can be reduced by management of the runoff in vicinity of the mine. Channel diversion, dikes, or conduits are possible means of controlling runoff.

In subsurface mining of vein type deposits, the space formerly occupied by the ore is usually backfilled as mining proceeds. In most of the mines in the Pacific Northwest, sand instead of waste rock is used for backfilling. In this "sandfill" process, the sand fraction is separated from the mill waste by cyclone separators and

is returned to the mine in a water stream. After deposition in the mine, the sand readily drains and consolidates to form a stable working surface for subsequent mining operations. When sand filling is underway, the normal underground settling of the wastewater in underground sumps is not adequate to remove the suspended solids and the resulting mine drainage is often very turbid. (See Appendix C10).

At most mines, the cyclone separators are located above ground and the added waste in the mine drainage is chiefly the water used to transport the sand into the mine. At one mine, the collar of the shaft is located about two miles back in the mountain from the portal of the adit. To pump the sand to the shaft without it settling out in the pipe, mill effluent is pumped into the mine to a separator located near the shaft. The silt and clay sized materials, after separation, are discharged into the mine drainage ditch and flushed out of the mine to a tailings pond. The sand is stored in a large underground excavation for mine filling. When sand separation is underway, the drainage from this mine contains the fine sediment and chemicals from the milling operation.

Other types of waste carried by mine drainage include sanitary wastes and oil and grease that are washed, dumped or spilled into the mine drainage. Oil may become more of a problem in the future as some mines are converting to diesel hauling equipment instead of electric rail equipment. U. S. Bureau of Mines Regulations 30CFR 31.9c(2) and 32.9e state that "Underground repair shops and storage spaces should be lined with incombustible material, and doors,

or other closures should be incombustible material. The floor should be impervious to oil and should slope to a sump, so that spilled oil may be collected and removed. A supply of sand should be kept on hand to aid in fighting fires or to absorb spilled oil". These are safety regulations promulgated under Public Law 89-577, Metal and Nonmetal Mine Safety Act. These are good environmental regulations and similar precautions should be extended to fuel transfer areas. The waste oil should not be dumped into the tailings pond or into a sanitary landfill but it should be removed from the mine and utilized for dust control or road oiling at the mining facility. In addition, large amounts of nitrate explosives are also used in mining and undoubtedly contribute some ammonia and nitrate to the mine drainage.

The following table shows the mine drainage disposal practices at the larger underground mining operations in the Pacific Northwest. Their locations are shown on Figure 1 (page 21).

TABLE I

MINE DRAINAGE DISPOSAL PRACTICES

	Mine	Practice
1.	Bunker Hill Mine	Mine drainage is discharged along with mill wastes into a large tailings pond. Decant pipe discharges effluent to South Fork Coeur d'Alene River.
2.	Cresent Mine	Mine drainage is discharged directly into Big Creek, a tributary of the South Fork Coeur d'Alene River.
3.	Dayrock Mine	Mine drainage is discharged directly to Ninemile Creek, a tributary to the South Fork Coeur d'Alene River.
4.	Galena Mine	Mine drainage is discharged along with mill waste into a series of tailings ponds. Effluent from tailings ponds is either pumped for industrial use at the mill or discharged to Lake Creek, a tributary to the South Fork Coeur d'Alene River. Combined discharge is about .7 MGD.
5.	Lucky Friday Mine	Mine drainage is discharged directly to Gold Hunter Creek, a small tributary to the South Fork Coeur d'Alene River.
6.	Knob Hill Mine	Mine drainage is pumped to a small pond near the No. 1 shaft. Pond discharges to Eureka Creek by subsurface percolation.
7.	Pend Oreille Mine	Mine drainage is discharged directly into the Pend Oreille River.
8.	Star-Morning Mine	Mine water is discharged directly to Slaughterhouse Gulch Creek, a tributary to the South Fork Coeur d'Alene River, and part is discharged to the Star Tailings Pond.
9.	Sunshine Mine	Mine drainage is combined with mill waste and discharged to a large tailings pond. Effluent from pond discharged to Big Creek, a tributary to the South Fork Coeur d'Alene River.

Table 2 gives some miscellaneous chemical analyses of mine water from a few mines in the Pacific Northwest. The quality of mine drainage will vary greatly with the specific operations going on within the mine, from season to season, and from mine to mine. The discharge of mine drainage from an active mine or for that matter, an inactive mine, directly to a stream without settling or treatment can be a serious source of water pollution.

Mine drainage from an active mine can contain many types of pollutants, and a settling pond for mine drainage can serve as a primary treatment facility. The pond, if it has sufficient holding capacity, can also serve as an emergency retention area in case of a spill of oil or chemicals into the mine drainage system. Where convenient, the mill tailings ponds can be used to treat mine drainage. Mine water can be used as a source of industrial process water for milling operations. At some mines, the industrial use of mine water would result in little or no waste water being discharged to the environment.

In the future, the effluent from many settling ponds will not be adequate to meet Federal effluent standards and additional treatment of the mine water will be required. In such cases, the use of mine water as an industrial supply for milling operations would minimize the quantity of waste water requiring additional treatment.

Ore Concentrating

In a metal mining operation, the ore generally contains a large amount of worthless rock that must be separated from the metal compounds before the ore can be smelted or refined. This operation is generally

TABLE 2

ANALYSIS OF MINE DRAINAGE FROM ACTIVE MINES

	1	2	3	4	5	6	7	8	9	10
	Bunker Hill Kellogg Tunnel	Bunker Hill 1/ Kellogg Tunnel	Bunker Hill Reed Tunnel	Bunker Hill 2/ Reed Tunnel	Cresent	Cresent 2/	Lucky Friday	Lucky Friday 2/	Star Morning	Star Morning 2/
Flow MGD				.49		.7		.38		.17
Specific Conductance			475	500	195	150	110	720	420	
Total Solids Mg/l				624		168		620		604
Total Dissolved Solids Mg/l				430		140		312		590
Total Suspended Solids Mg/l				194		28		308		14
Total Hardness Mg/l				78		40		92		232
pH			3.2	3.2	6.4	6.8	6.6	8.4	7.3	7.9
Oil and Grease				1.5		2		4.5		7
Ammonia as N Mg/l				3.0		1.07		2.9		.2
Kjeldahl Nitrogen Mg/l				3.3		7.04		3.1		3.5
Nitrate as N Mg/l				1.8		.14		1.9		.35
Phosphorus Mg/l				.25		.01		.2		.2
B.O.D. 5 day Mg/l				45		25		8		16
Chemical Oxygen Demand Mg/l				1		0		34		1
Alkalinity as $CaCO_3$ Mg/l				259		30		164		108
Chloride Mg/l				21		4		10		1.3
Sulfate Mg/l				275		75		37		57
Fluoride Mg/l				.07		.09		1.26		.21
Antimony Mg/l		.3	.06		.16		.03		.07	
Arsenic Mg/l			.07		.05		.005		.005	
Cadmium Mg/l			.05	.08	.001		.001		.008	.008
Chromium Mg/l			.004		.005		.004	.012	.005	
Copper Mg/l		1.1	.06	.05	.47	.19	.03		.01	.03
Iron Mg/l				29		4.4		4.0		1.6
Lead Mg/l	3.8	18.0	2.5	1.3	.06	.1	.005		.2	.18
Manganese Mg/l				25		3.6		.5		.4
Mercury Mg/l	.001	.01	.003	.001	.0005	.001	.005		.001	.005
Zinc Mg/l	49	18.8	.09		.07	.8	.7	.87		.5

1/ Sand filling underway
2/ Data from mining company

done at a mill located near the mine portal to eliminate costly transportation of worthless rock.

In a mill or concentrator, the ore is generally crushed to a "minus one inch" size and fed into a ball or rod mill. A ball or rod mill consists of a large revolving horizontal cylinder that is partially filled with steel balls or rods. The revolving action of the cylinder produces a tumbling action that grinds the ore to the size of fine sand or silt. Water is added during the grinding process and the ground ore slurry is pumped to the next step of separation.

In most mills in the Pacific Northwest, the ore minerals are separated from the waste rock by a flotation process. This process consists of treating the finely ground ore with chemicals that produces a water-repellent coating on the specific ore mineral to be removed. The treated ore then moves into a series of flotation cells which are equipped with agitators that keep the ore in suspension and also draw air into the cells to create a bubbling action. A frothing agent is added to the mixture to produce a froth or foam. The ore minerals adhere to the foam and are removed at the top of each cell. Generally, the pulverized ore is recycled through several flotation cells to insure that most of the ore minerals are removed.

The waste rock and iron from the milling operation are removed from the last flotation cell and flushed to waste as a slurry or sent to a "cyclone" for sand removal. In some mills, the waste from the first series of flotation cells is retreated with other chemicals and

processed through a second series of flotation cells to remove another ore mineral.

After the froth or foam is removed from the flotation cells it is broken down by a water spray to form a mineral bearing slurry. The slurry is piped to a large tank called a thickener where the minerals settle out and the excess water overflows to waste. The final milling process consists of further drying the ore concentrate by a vacuum filter process or kilns. The ore concentrates are then ready for shipment to a smelter or refining plant.

All of the large heavy metal mines in the Pacific Northwest with the exception of one mine have mills located at or near the mine portal. At this mine, the ore is hauled some 8 miles by truck to a mill at an adjacent mine. Table 3 describes the mill waste disposal practices at the larger mills in the Pacific Northwest. In general, it is desirable to locate the mill in proximity to the mine portal. Problems in waste management and water supply, however, may make the mine portal site less desirable than some more environmentally compatible area. For example, it may be desirable to transport all the ore mined within a municipal watershed to some point outside the watershed for processing.

It has been demonstrated at the Galena Mill that mill waste can be settled and the waste water recycled back into the milling operation. This type of system is also being planned at the Bunker Hill Concentrator. Recycling of mill waste is extremely important in reducing the quantity of waste requiring further treatment.

TABLE 3

MILL WASTE DISPOSAL PRACTICES

	Mine	Practice
1.	Bunker Hill Mine	Waste discharged to large tailings pond. Effluent to South Fork Coeur d'Alene River.
2.	Clayton Silver Mine	Waste discharged to tailings pond. Effluent to Kinnikinic Creek, a tributary to the Salmon River.
3.	Dayrock Mine	Waste discharged to small tailings pond. Effluent to Ninemile Creek.
4.	Galena Mine	Waste discharged to a series of four small tailings ponds and two clarifying ponds. Effluent is either recycled back to the mill or discharged to Lake Creek.
5.	Lucky Friday	Waste pumped across the town of Mullan and discharged into a tailings pond. Effluent to South Fork, Coeur d'Alene River.
6.	Knob Hill Mine	Waste is pumped to a tailings pond. Effluent from pond is discharged to Eureka Creek.
7.	Nickel Mountain Mine	Waste is pumped to large tailings ponds. Ponds overflow to Cow Creek during wet seasons.
8.	Pend Oreille Mine	Mill wastes are discharged to a tailings pond prior to discharge to the Pend Oreille River.
9.	Star-Morning Mine	Mill wastes are piped some six miles down the Canyon Creek Valley from Burke to three large tailings ponds. Effluent from the ponds are discharged into Canyon Creek.
10.	Sunshine Mine	Mill effluent treated with a flocculating agent and piped several miles down the Big Creek Valley to a large tailings pond. Effluent from pond to the South Fork of the Coeur d'Alene River.

Tailings Ponds

One of the most serious types of pollution problem related to mining operations is the sudden failure of a tailings pond dike or dam and the subsequent release of a large volume of toxic waste into a water course. Such a failure may be caused by slumping, or piping through the dike or dam. Failure can also be caused by wave action that overtops or otherwise erodes the dike, or by leakage that develops around the decant pipe where it extends through the impounding structure. Some tailings ponds are constructed to receive runoff from surrounding areas. Under extreme conditions, excessive runoff from adjacent drainage areas may also cause a sudden filling and failure of a dike or dam. The release of a large quantity of toxic waste can destroy all fish and aquatic organisms for a considerable distance downstream. The amount and extent of damage from the failure of a tailings pond dam is, of course, dependent upon the toxicity and volume of the waste and the size or flow of the receiving stream.

The developers of new mining projects often state that there will be no water pollution because all of the mill waste water will be recycled with no waste discharge from the tailings pond. This type of facility can only exist under certain climatic and hydrologic conditions. In areas where the amount of annual evaporation exceeds the amount of annual precipitation, it may be possible to construct and operate a non-overflow tailings pond. In areas where annual precipitation exceeds annual evaporation, all tailings ponds will eventually have a discharge. The discharge may be seasonal and occur

only in the rainy season. All tailings ponds are suspected to have seepage discharges.

Figure 1 is a map of the Pacific Northwest showing the general areas where annual precipitation exceeds annual evaporation. It would be difficult to construct tailings ponds in these areas without having a waste water discharge either to a water course, to a ground water aquifer, or both.

Table 4 gives the chemical characteristics of effluents from tailings ponds at some active mines and mills in the Pacific Northwest. The values at the Bunker Hill pond (see Appendix C14) are exceptionally high in comparison to other tailings pond discharge because the Bunker Hill pond received waste from a phosphoric acid plant, an electrolytic zinc plant and Kellogg municipal sewage in addition to mine drainage and mill waste. The other tailings ponds receive only mill wastes or a combination of mill wastes and mine drainage.

In areas where evaporation is relatively high and precipitation is low, a tailings pond having a large surface area could operate as a "non-overflow" pond. The recycling of waste water from the tailings pond back to the mill would substantially reduce the size of the required pond. At some mines where the flow of mine water is large, the construction and operation of a "non-overflow" pond for the mill waste would be feasible only if mine water is treated and discharged separately.

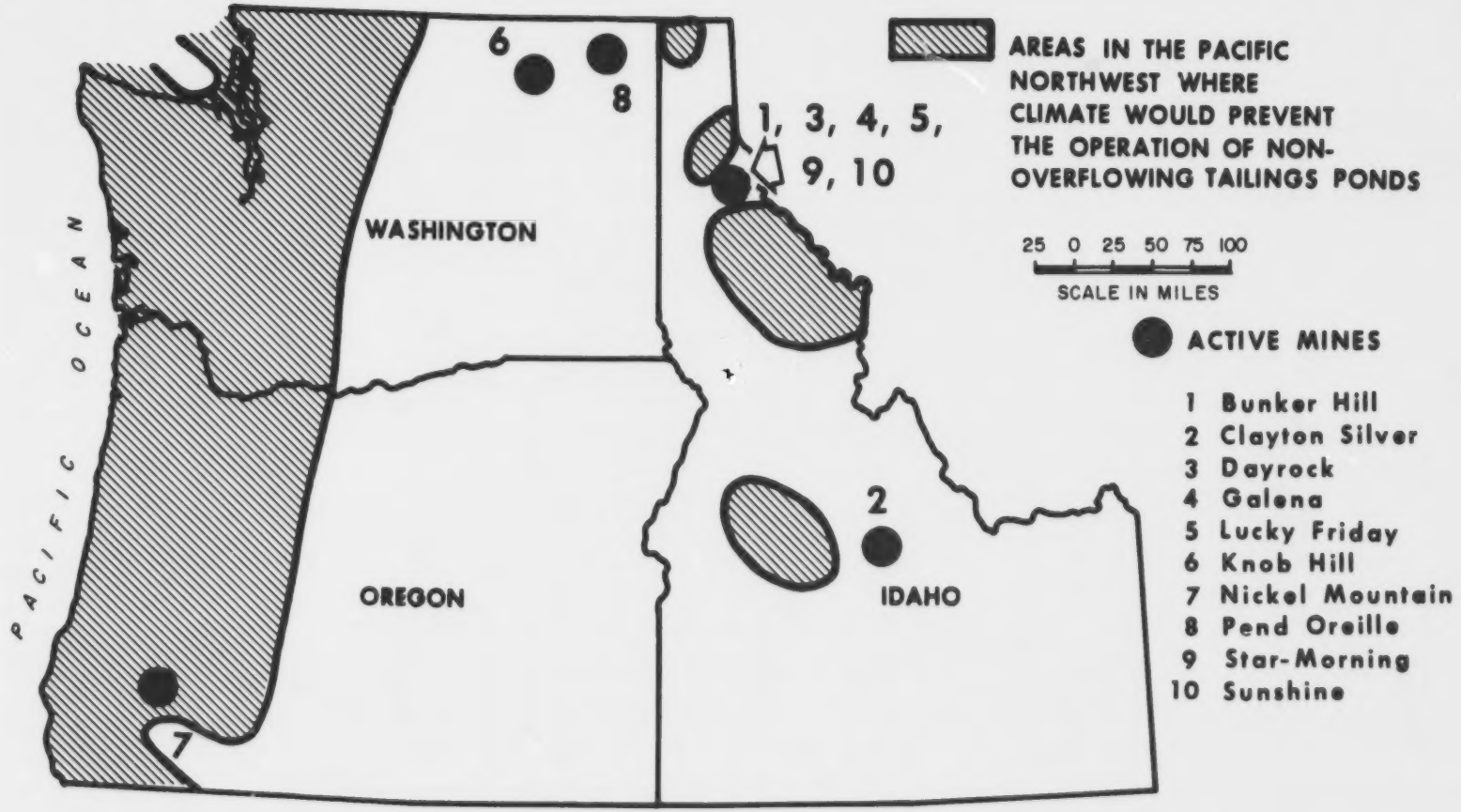

FIGURE 1 AREAS IN PACIFIC NORTHWEST WHERE ANNUAL PRECIPITATION GENERALLY EXCEEDS ANNUAL EVAPORATION

TABLE 4

CHEMICAL CHARACTERISTICS OF EFFLUENTS FROM TAILINGS PONDS
AT ACTIVE MINES (DATA FROM MINING COMPANIES)

	Bunker Hill	Dayrock	Galena	Knob Hill	Lucky Friday	Nickel Mountain	Pend Oreille	Star Morning	Sunshine
Flow MGD	3.6	.29	.7	.12	.86	.12	.43	2.1	1.5
Specific Conductance		450	350	860			400	730	1250
Total Solids Mg/l	1786	90	280	700	178	180	312	644	541
Total Dissolved Solids Mg/l	1360	80	264	660	126	168	300	622	525
Total Suspended Solids Mg/l	426	10	16	40	52	12	12	22	16
Total Hardness Mg/l	728	112	172	260	80	152		272	36
pH	3.2	7.5	7.4	8.4	8.2	9.0	7.4	7.7	8.5
Oil and Grease Mg/l	5	.6	13	4.5	4.5			6	50
Ammonia as N Mg/l	4	4	6	3.8	.2	.4	6	2	.09
Kjeldahl Nitrogen Mg/l	6.4	5	7	6	3.5	1.4	7	4.5	.6
Nitrate as N Mg/l	1.8	4	5	4.4	1.5		3.1	1.5	.01
Phosphorus Mg/l	2.5	.04	.05	.16	.1	.05	.1	.03	.03
B.O.D. - 5 day Mg/l	30	1	10	2	2	2	19	10	67
Chemical Oxygen Demand Mg/l	8	11	8	75	17	8	24	19	84
Alkalinity as $CaCO_3$ Mg/l	450	122	132	190	72	134	205	78	78
Chloride Mg/l	150	6	7	4.5	2.2			7	39
Sulfate Mg/l	550	18	27	112	20	7		85	.64
Fluoride Mg/l	.36	.24	.29		.27	.48		.28	.29
Cyanide Mg/l		.01	.06					.52	
Antimony Mg/l	.001		.5						21.9
Arsenic Mg/l	.9								5.0
Cadmium Mg/l	1.7	.01	.01		.02			.07	
Chromium Mg/l	.016	.05	.05					.008	
Copper Mg/l	.47	.008	.15		.02			1.7	
Iron Mg/l	171	.2	.7	.05	1.0	.2		1.7	21
Lead Mg/l	18	.5	.02		.12			.2	
Manganese Mg/l	83	.3	.9		.17	.03		.8	2.3
Mercury Mg/l	.007	.0005	.001		.005			.005	
[illegible]	53	.39	.07		.05			.9	1.1

The effluent from a tailings pond can generally be treated by careful pH adjustment followed by settling to remove the troublesome pollutants prior to its discharge to a stream. If a tailings pond dike should leak or contaminated water should seep into the ground through the floor of the pond, it may be impossible to prevent pollution of ground water of adjacent streams unless the ponds are sealed and stabilized to prevent leakage. Ground water pollution can be very serious. It is difficult to remove and will exist for a very long period of time. A composite chemical analysis of ground water from several wells in the South Fork Coeur d'Alene River Valley below Kellogg, Idaho is given in Table 5 (sample from an industrial supply system supplied by several wells). This analysis shows that ground water pollution can make a ground water supply unsuitable for many purposes.

TABLE 5

ANALYSIS OF GROUND WATER
COEUR D'ALENE RIVER VALLEY, IDAHO

	Ground Water	Drinking Water Standards
Arsenic	.005 mg/l	.050 mg/l
Antimony	.040 mg/l	-
Cadmium	.040 mg/l	.010 mg/l
Chromium	.006 mg/l	-
Copper	.041 mg/l	1. mg/l
Iron	.100 mg/l	.3 mg/l
Mercury	.007 mg/l	-
Zinc	25. mg/l	5.mg/l

EPA has had the opportunity of examining several tailings ponds that were being constructed or enlarged during the past year. In some, permeable alluvial sand and gravel were used for dike construction while mine waste rock was being used in others (see Appendix C5, C7, and C8). In both types there was little or no compaction of the material except by the bulldozers used to spread the material. These tailings ponds will certainly prove effective in removing the suspended materials from the mine and mill wastes, but leakage from these ponds through the dikes or through the underlying alluvium will create new and uncontrolled sources of water pollution. It is likely that the amount of seepage from older tailings ponds actually increases as the decant pipe is raised and the hydraulic gradient from the tailings pond to an adjacent stream is steepened. The treatment of the overflow from existing tailings ponds may prove inadequate to abate water pollution problems and it may become necessary for mining companies to seal or undertake other remedial action to reduce water pollution caused by leakage.

Tailings pond dikes and dam construction should follow the same engineering requirements that are employed in the design and construction of earth dams for the storage of water. Sites should be evaluated from the standpoint of safety and the structure should be designed to reduce leakage to a minimum and to prevent structural failure. Cutoff walls may be required beneath dikes and dams, earth materials used in construction should be evaluated in a soils laboratory for their suitability for use in the dam, and the moisture and compaction

of the fill materials should be controlled during construction to prevent subsequent failure of the structure. Pre- and post-construction monitoring of hydrologic conditions should be mandatory. Some states have regulations relating to the construction of earth dams for water reservoirs but these regulations are not generally applied to waste disposal ponds.

The feasibility of abating ground water pollution caused by leakage from specific tailings ponds is beyond the scope of this report. To remedy water pollution problems at a particular tailings pond would require special investigations including test drilling and hydrologic studies. To prevent ground water pollution problems, new ponds should (1) be located in areas where soil conditions will keep leakage to a minimum or (2) the bottom and sides of the pond should be adequately sealed with clay, plastic or other suitable material to reduce leakage. The peripheral waste discharge into a tailings pond generally results in the coarser, more permeable material being deposited around the margins of the ponds. This practice can facilitate leakage through the dike or dam and increase the possibility of water pollution.

Angular mine rock is generally better material for constructing tailings pond dams and dikes than rounded alluvial material rock since it forms a less permeable and more stable structure. In large ponds, coarse rip-rap rock around the margins may be required to reduce wave erosion. Log booms and compartmentation in large ponds will also reduce wave erosion.

Normally, the decant pipe is used as an overflow for the pond and is raised in increments as the tailings pond is filled with sediments. If the entire holding capacity of a tailings pond is utilized for holding effluent, a longer retention time in the pond will increase pond efficiency in removing suspended materials. Filling existing ponds to capacity without first evaluating their safety as hydraulic structures is not recommended. Tailings ponds should also be constructed with emergency spillways to prevent overtopping of the dike or dam in case the decant pipe is plugged or collapses, or a torrential storm discharges an overload of run-off to the pond.

When the pond is filled with sediment, the mining company should revegetate or stabilize the sediments. Mill wastes are generally toxic to plants and some soil conditioning is required. This may include mixing the tailings with soil, possibly soil that was stockpiled when the pond was constructed, with sewage plant sludge, or with sand or other suitable material. A good growth of vegetation will reduce both wind and water erosion. If it is not feasible to revegetate, a one to two foot layer of mine rock spread over the surface of the pond will reduce both wind and water erosion. This material can be stockpiled near the pond during mining for use as cover material when the pond is full.

Recommended Practices at Active Mines

Exploration and Development

1. ALL ACCESS AND WORK ROADS, WHETHER ON PUBLIC OR PRIVATE LAND OR ON THE MINING CLAIM BEING EXAMINED SHOULD BE LOCATED, DESIGNED, CONSTRUCTED AND MAINTAINED TO REDUCE EROSION PROBLEMS TO A MINIMUM.

2. ALL PITS, CUTS, AND TRENCHES EXCAVATED DURING MINERAL EXPLORATION SHOULD BE RESTORED TO NEAR THEIR ORIGINAL TOPOGRAPHY AND REVEGETATED.

3. ALL TEST HOLES, AND MAJOR WATERBEARING ZONES ENCOUNTERED IN ADITS, DRIFTS AND SHAFTS THAT WOULD DISCHARGE MINERALIZED WATER TO THE ENVIRONMENT SHOULD BE GROUTED OR OTHERWISE SEALED OFF PRIOR TO SITE ABANDONMENT TO REDUCE THE DISCHARGE TO A MINIMUM.

Mining

4. ALL MINE DRAINAGE SHOULD BE TREATED IN A SETTLING POND PRIOR TO DISCHARGE TO A WATER COURSE.

5. IF FEASIBLE, THE EFFLUENT FROM THE MINE DRAINAGE SETTLING POND SHOULD BE USED AS AN INDUSTRIAL WATER SUPPLY FOR MILLING OR OTHER MINE USES.

6. WHEN CLEANING UNDERGROUND MINE DRAINAGE SUMPS OR TANKS, THE SEDIMENT SHOULD NEVER BE FLUSHED TO A WATER COURSE OR DEPOSITED WHERE IT WILL BE WASHED INTO A LAKE OR STREAM.

7. SURFACE WATER AND GROUND WATER FLOW SHOULD BE CONTROLLED WHERE FEASIBLE TO PREVENT THEIR ENTRY INTO MINE WORKINGS.

8. LARGE QUANTITIES OF GASOLINE, DIESEL OIL, PETROLEUM PRODUCTS, AND TOXIC INDUSTRIAL CHEMICALS, EITHER ON THE SURFACE OR UNDERGROUND SHOULD BE STORED IN DURABLE TANKS OR CONTAINERS AND WITHIN AN AREA SURROUNDED BY DIKES TO CONTAIN OR PREVENT ESCAPE IN CASE OF A MAJOR SPILL OR LEAK.

9. ALL UNDERGROUND SERVICE AREAS FOR DIESEL POWERED EQUIPMENT AND UNDERGROUND FUEL TRANSFER AREAS SHOULD BE EQUIPPED WITH DRAINS WITH SUMPS THAT WILL PREVENT PETROLEUM WASTES AND SPILLS FROM GAINING ACCESS TO THE MINE DRAINAGE SYSTEM.

10. WHERE MINING OPERATIONS CALL FOR THE SURFACE STOCKPILING OF LOW GRADE ORE, LEACHING SHOULD BE CONTROLLED BY DIVERTING SURFACE DRAINAGE AROUND OR AWAY FROM THE PILE OR PILES.

Milling

11. IF THE LAND AREA OR SOIL CONDITIONS ARE NOT SUITABLE FOR SEPTIC TANK DRAIN FIELDS, TREATED SANITARY WASTES FROM THE MINING AND SUPPORT FACILITIES SHOULD BE DISCHARGED TO THE MILL TAILINGS POND.

12. WHERE MILLING AND WASTE DISPOSAL AT A SITE NEAR THE MINE PORTAL WILL CONFLICT WITH OTHER LAND AND WATER USES, TRANSPORTING THE ORE TO A MORE ENVIRONMENTALLY COMPATIBLE MILL SITE SHOULD BE EVALUATED IN THE PLANNING STAGE OF MINE DEVELOPMENT.

13. WHERE METALLURGICAL PROCESSES PERMIT, MILL WASTE WATER SHOULD BE RECYCLED FOR MILL USE.

Tailings Ponds

14. IF CLIMATIC CONDITIONS PERMIT, TAILINGS PONDS SHOULD BE DESIGNED, CONSTRUCTED AND OPERATED SO THAT THERE IS LITTLE OR NO DISCHARGE.

15. TAILINGS POND DIKES OR DAMS SHOULD BE DESIGNED AND CONSTRUCTED TO PREVENT LEAKAGE, SLUMPING AND OVERTOPPING, INCLUDING SUCH FEATURES AS CUT-OFF WALLS, AND THE COMPACTION OF MATERIALS SIMILAR TO THAT GENERALLY REQUIRED IN WATER STORAGE STRUCTURES.

16. ALL TAILINGS PONDS SHOULD BE CONSTRUCTED WITH A SPILLWAY OR OTHER ADEQUATE OVERFLOW STRUCTURE THAT WILL PREVENT OVERTOPPING AND SUBSEQUENT FAILURE OF THE DIKE OR DAM.

17. IF POSSIBLE, TAILINGS POND DIKES AND DAMS SHOULD BE CONSTRUCTED OF ANGULAR WASTE ROCK FROM MINING OPERATIONS RATHER THAN ROUNDED ALLUVIAL MATERIALS.

18. IF POSSIBLE, ALL TAILINGS PONDS SHOULD BE LOCATED OFF CHANNEL SO THAT SURFACE RUNOFF WILL BYPASS THE POND.

19. CONDUITS CARRYING SURFACE DRAINAGE SHOULD NOT BE LOCATED BENEATH TAILINGS PONDS.

20. THE FLOOR OF NEW TAILINGS PONDS LOCATED ON PERMEABLE MATERIAL SHOULD BE ADEQUATELY SEALED TO PREVENT LEAKAGE PRIOR TO FILLING THE POND.

21. BOOMS OR DIKES WITHIN LARGE TAILINGS POND SHOULD BE USED TO REDUCE WAVE ACTION AND EROSION.

22. WOOD CRIBS SHOULD NEVER BE USED AS INTEGRAL PARTS OF TAILINGS POND DIKES OR DAMS.

23. MINE OPERATORS SHOULD DESIGN, CONSTRUCT AND OPERATE TAILINGS PONDS SO AS TO PROVIDE FOR THEIR REVEGETATION UPON FILLING OR ABANDONMENT.

24. A WATER COURSE SHOULD NEVER BE USED TO TRANSPORT MINE AND MILL WASTE TO A TAILINGS POND.

25. TAILINGS PONDS SHOULD NOT BE USED AS BURIAL GROUNDS FOR TOXIC CHEMICALS.

PART 2 - WATER QUALITY CONSIDERATIONS AT ABANDONED MINES

EPA has examined numerous abandoned or inactive mines and test openings in the Pacific Northwest. The water pollution problems associated with some of these mines are of two general types: (1) discharge of mineralized mine drainage into a stream, and (2) erosion and leaching of mill tailings. Many of the abandoned mines are still in private ownership or are located on mining claims and would be re-opened if the price of metals rises enough to make their operation profitable.

This part of the report will not go into the legal problems related to the abatement of pollution from abandoned mines except to state as a general rule that the land owner assumes the responsibility of any problem resulting from the condition of the land at the time he takes title to the lands. In the case of unpatented mining claims on Federal land, the Federal agencies administering the land upon which the claim is located, are not legally responsible for the water pollution caused by an inactive mine on a claim. This is because a mining claim perfected under the 1872 Mining Law, though unpatented, has the effect of a grant by the United States, and is regarded as property in the fullest sense of that term and may be sold, transferred, mortgaged and inherited without infringing any right or title of the United States. The owner of the claim should therefore be responsible for pollution caused by inactive mines on the claim. However, if the owner of a mining claim should abandon his claim, the pollution problems on the claim would pass to the Federal government for possible abatement with little recourse, if any, against the claimant.

Mine Drainage

Drainage from most inactive metal mines in the Pacific Northwest contains substantial concentrations of dissolved metals. The most common constituents of mine drainage in this area are iron, manganese, zinc and copper. Fortunately, most of the abandoned mines have relatively small flows and have little or no effect on the receiving streams. Inactive mines causing pollution problems have not been completely inventoried, but some are located in Oregon, Washington and Idaho. The analyses in Appendix B give the chemical characteristics of some mine drainage water, and picture C12 in Appendix C shows a water pollution problem associated with an abandoned mine.

One of the largest abandoned mines is located in the heart of the Northern Cascades at Holden, Washington. This particular mine produced some 66 million dollars in copper, gold, zinc and silver. At one time, it employed some 500 people and was the largest mining operation in the State. This mine was closed and abandoned in 1957. When it was examined in 1972, the mine drainage had a flow of about 2 cfs and formed a tributary to Railroad Creek which is tributary to Lake Chelan. An analysis of the drainage from the Holden Mine is given in Appendix B.

The U. S. Forest Service reported that caving within the Holden Mine a few years ago caused a temporary sealing off of mine drainage. Eventually this seal broke and a large quantity of water discharged through the portal. This torrent resulted in substantial erosion and washed out a bridge over Railroad Creek. The environmental

damage resulting from this event was never determined. As a general rule, plugging or sealing a portal as a method of reducing or eliminating mine drainage will provide only temporary relief. This kind of seal can result in even more serious pollution problems if the seal should fail or if the mine water should break out at some other location.

As mentioned earlier in this report, the best method of minimizing pollution from mine drainage is to prevent surface water from entering workings and sealing or grouting permeable zones encountered within the mine. These practices can also materially reduce the cost of pumping mine drainage from the mine. If these practices have not been attempted during mining operations, they should be done as a prerequisite to closing or abandoning the mine. Once a mine has been closed and flooded, it could be a very costly project to attempt to reduce the amount of drainage.

In most cases it will not be feasible to attempt to reduce the flow of drainage from abandoned mines except where surface drainage has direct access to the workings. If it is desirable to correct a specific pollution problem, the treatment of the drainage may be the only practical solution.

Treatment of drainage can usually be accomplished by diversion into a settling pond and, in some cases, pH adjustment. Pollution abatement at some abandoned mines could be minimized by impounding and treating the drainage during the low stream flow periods and releasing the treated waste during peak flow periods. In some areas, like the Canyon Creek Valley in the Coeur d'Alene Mining District,

drainage from abandoned mines could be easily diverted into the existing tailings ponds.

Erosion and Leaching

Erosion and leaching of tailings is by far the greatest source of water pollution from abandoned or inactive mines in the Pacific Northwest. Erosion comes from surface streams flowing across the tailings and from streams flowing along the margins of the tailings ponds and eroding their sides (see Appendix C1, C2, C3 and C4). Land slides and slumping of tailings into a stream can also result in the sudden loading of toxic materials into the receiving water.

Leaching comes from water infiltrating into and flowing through the tailings. The leachates, which may be highly mineralized, tend to seep out near the margin of the tailings and create either a pollution problem near the tailings, or else at a remote location down the valley.

Other pollution problems associated with abandoned tailings include wind erosion and exhuming buried toxic chemicals by erosion. Wind erosion, besides creating an air pollution problem, can blow tailings into a stream or to a location where they are readily washed into a stream.

Waste chemicals are often collected in drums, and buried with the tailings during mining operation. Subsequent erosion of the tailings can bring these wastes to the surface where they can be washed into a stream. How many of these toxic time bombs are buried in abandoned tailings ponds is not known, but if present, they constitute a threat to water quality.

The large abandoned tailings ponds at Holden, Washington are prime examples of how abandoned tailings can result in water pollution. These particular ponds were constructed on Federal land under a special use permit. The mine has been abandoned, and the maintenance of these tailings is now a public responsibility.

The Holden tailings ponds exhibit all the conditions that contribute to water pollution. A stream flows across the tailings and washes them directly into Railroad Creek (Appendix C4). Railroad Creek is also eroding the side of the piles and the stream carries tailings into Lake Chelan. Small streams also flow onto the surface of the tailings and collect in ponds (Appendix C13). Water from these ponds infiltrates into the tailings and contributes to the leachate problem. Wind erosion of the tailings, which has also created a serious air pollution problem in the area, results in tailings being blown into Railroad Creek and onto the adjacent slopes where they are washed into the stream. These particular tailings ponds probably constitute the biggest threat to water quality in the Pacific Northwest from an abandoned mining operation. The problems observed at this mine point out the need for very strict controls over the design, operation, and abandonment of tailings ponds so that they will not become Federal liabilities after they are abandoned.

Recommended Practices for Closing a Mine

Mines

1. A SETTLING POND SHOULD BE PROVIDED FOR MINE DRAINAGE BETWEEN THE MINE AND THE RECEIVING STREAM.

2. SURFACE DRAINAGE SHOULD BE CONTROLLED OR ROUTED SO AS TO PREVENT THE DIRECT FLOW OF WATER INTO MINE WORKINGS.

3. PERMEABLE ZONES CONTRIBUTING SUBSTANTIAL QUANTITIES OF MINERALIZED WATER TO A MINE TUNNEL SHOULD BE PRESSURE GROUTED OR OTHERWISE SEALED OFF TO MINIMIZE MINE DRAINAGE.

4. SURFACE DRAINAGE SHOULD BE ROUTED AROUND MINE ROCK DUMPS TO REDUCE LEACHING.

5. IN OPEN PIT MINES, STREAM CHANNELS SHOULD BE MODIFIED TO REMOVE ALL BARRIERS TO FISH MIGRATION CAUSED BY THE MINING OPERATION.

Tailings Ponds

6. EROSION OF TAILINGS PONDS LOCATED ADJACENT TO STREAMS SHOULD BE CONTROLLED BY THE CONSTRUCTION OF A COARSE RIP-RAP FACING OR A DIKE TO PREVENT STREAM ENCROACHMENT.

7. SURFACE DRAINAGE THAT WOULD NORMALLY FLOW INTO A TAILINGS POND BE DIVERTED AROUND THE TAILINGS.

8. TO REDUCE EROSION, FILLED TAILINGS PONDS SHOULD BE EITHER RE-VEGETATED OR COVERED WITH A TWO FOOT LAYER OF WASTE MINE ROCK.

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9. TO REDUCE LEACHATE PROBLEMS, THE SURFACE OF FILLED TAILINGS PONDS SHOULD BE GRADED TO PREVENT PONDING, OR THE DECANT SYSTEM SHOULD BE MODIFIED TO REMOVE INCIDENT PRECIPITATION.

PART 3 - GUIDELINES FOR THE CONSTRUCTION OF MINE ROADS

Proper planning, location, design, construction, use, and maintenance of all roads - will reduce soil erosion problems. The following guidelines have been assembled under four headings: location, design, construction and maintenance. They are modified from the Federal Water Pollution Control Administration report "Industrial Waste Guide - Logging Practices, 1970".

Location

1. Locate all roads to avoid, or design them to counteract, unstable soil areas. Select the gradient which will provide for a stabilized road prism with proper drainage. Fit road locations to the topography so that minimum alterations of natural conditions will be necessary.

2. Locate roads on natural benches, ridge tops, and flatter slopes to minimize harmful disturbances of the terrain and to enhance the stability of the roads. Use all available topographic surveys, soil-type maps, and other soils and geologic information to select locations which avoid steep slopes and unstable soils. Field observation and evaluation is advisable in problem areas. Give full consideration to soil strength and cohesion to determine the proper cut-and-fill slope rations and to specify spacing for relief-drainage culverts.

3. Locate roads on stable areas well away from streams. Avoid routes through the bottoms of steep narrow canyons; through slide areas; through steep, naturally dissected terrain; through slumps;

through marshes or wet meadows; through ponds; or along natural drainage channels. Where alternative locations through stable areas are not available, incorporate corrective stabilization measures into the road design.

Design

Prescribe for each road those design specifications that are best adapted to the given slope, landscape, and soil materials. Use a balanced design or provide waste or borrow areas that will produce a minimum of damage to soils and water. Cross streams where channel and bank disturbance will be minimal. Avoid excessive sidehill cuts and fills, especially near stream channels. Plan for retaining walls or rip-rap where needed to increase the stability of fill embankments and cuts and to protect fill embankments from water erosion.

1. In critical situations, design for full-bench construction rather than part bench and part compacted fill. Haul all excavated waste material to safe bench or cove locations.

2. Reduce backslope sloughing by rounding the tops of cut slopes.

3. Design fill at an angle less than the normal angle of repose.

4. Clear trees and other vegetation for only the minimum essential width required for construction and maintenance of the road and choose the design alignment and minimum road width necessary to serve traffic needs.

5. Divert or otherwise dispose of all drainage so that it does not pass over or collect in new cuts, fills, borrow areas, or waste

dumps. Do this by providing bridges or adequate culverts at all natural water courses both for permanent and temporary access or haul roads. Avoid channel changes and stabilize the fill material of the approaches with rip-rap or abutments. Where culverts must be installed in large fills, use concrete or heavy rip-rap headwalls and wingwalls to prevent erosion of the fill and to help direct the passage of debris through the major culverts. To prevent disturbance of stream channel, use rip-rap, gabions (wire baskets full of large rocks), or other structures where needed to protect roads that must be constructed in canyon bottoms.

6. Design culverts or bridges large enough to carry at least a 25-year frequency storm. West of the Cascades, use a 24-inch or larger diameter culvert for all live stream crossings to minimize fish migration blockages.

7. In order to reduce fish passage problems and pipe abrasion, design to use bridges or "true-arch" (bottomless) culverts on steep slopes. In locations where bridges or bottomless culverts are impractical, design for culverts with installed baffle plates to provide for fish passage through the culvert. Orient culverts with natural stream channels and extend them beyond the fill slopes. For anadromous fish passage, provide an entrance pool at least 3 feet deep and 12 feet long at the outflow end of the culvert. Stabilize the pool with barrier logs to prevent erosion. Place the logs so there is no impassable drop between the culvert and the stream.

8. Provide an adequate drainage system that will reduce both the runoff concentration in the roadway and the saturation

of poorly drained soils. Where justified by the volume of traffic or the type of soil the road crosses, use roadside ditches and culverts. Give each relief culvert a minimum slope of one percent and provide a sediment-catching basin at the entrance. Use downspouts and other slope protection measures to avoid erosion of fill areas.

9. Provide dips, water bars, and cross drains in order to prevent water accumulations from eroding and gullying skid trails. Put such structures close enough together so the collected water will be small in amount and can easily be diverted off the road into safe spreading areas.

10. Design temporary roads to drain by outsloping wherever possible. On long slopes, space dips in the road to assure diversion of runoff from the road surface. For fills with culverts, place a dip at the downgrade approach so that in the case of a flood or plugged culvert, the excess water may flow over the road at that point. Use fords or other low level crossings for small streams that have a high upstream debris hazard.

11. Prevent muddy and turbid waters from draining off the roadbed and into streams. Where necessary, make provisions to build up the surface of dirt roads with rock, pave, or otherwise stabilize road surfaces in order to minimize subgrade failures, road surface erosion and road maintenance grading. For temporary paving, use emulsified asphalt where applications of oil or sulfite-waste liquor type dust inhibitors could possibly wash into and contaminate receiving waters.

12. Obtain all roadrock and gravel from dry quarries, or

from dry channels that are provided with adequate protection against sediment production. Do not "wet" mine (dredge) such road rock or gravel from live stream channels.

Construction

In many places, careless and improper construction of a high mountain road can nullify all the effort expended in well considered design and location. Numerous mud-rock slides and land slumps have started at the edge of such roads and, once started, have carried through hundreds of feet of forested slopes. Poor construction and inadequate drainage have triggered land slumps in watershed after watershed and have resulted in the most serious form of accelerated erosion.

High quality road construction should be insisted upon by the land owner or his representative. Regular inspections should be made during construction by a qualified engineer with authority to assure that road construction meets design requirements.

Therefore, during all phases of road construction, protect water quality by using every possible and applicable soil and water conservation measure.

1. Where the road design calls for full bench construction, make the full cut, end-haul excess excavation from the cut, and deposit it in stable locations well above the high water level. Do not deposit waste materials directly into any stream channel. Where necessary, compact all fill material to reduce the entry of water and to prevent the fill material from settling. Do not place any woody or other organic debris in the fill of any road.

2. Collect all construction-area drainage and keep it out of the streams. Use seepage pits or other confinement measures to prevent diesel oil, fuel oil, or other liquids from running into streams. Use drip collectors on oil-transporting vehicles. Divert water for sprinkler trucks a sufficient distance from the source to the filling point to prevent overflow spilling or flushed tank water from reaching the stream.

3. Keep soil disturbances to a minimum by constructing roads only when soil moisture conditions are favorable. Rough grade new road only as far as that road can be completely finished during the current construction season. Finish ditches and drainage installations on the section being worked upon before opening of another section or before shutting down construction for the season.

4. Fully backslope each graded section except where vertical cut banks are more stable than sloping ones. In critical slump areas, grade large cuts to slopes of not more than 1.75 to 1 and use horizontal drain pipes. Also, protect all large fill areas with surface drainage diversion systems. Place culverts so as to cause the minimum possible channel disturbance and keep fill materials away from culvert inlets and outlets. During road construction do not permit earth moving activities when the soils are saturated. Allow road machines to work in stream beds only for laying culverts or constructing bridge abutments. Divert streamflow from the construction site whenever possible in order to prevent or minimize turbidity.

5. Clear drainage ways of all woody debris generated during road clearing or construction. Windrow the clearing debris and crush

it outside the road prism where burning of the debris is necessary to reduce the fire hazard, prevent insect infestations, or to improve the aesthetics.

Maintenance

Fully and thoroughly maintain all portions of the road system to prevent water quality degradation from accelerated erosion during heavy rainstorms. This includes the regular maintenance of drainage diversions, such as cleaning culvert inlets before and keeping them clean during the rainy season to diminish the danger of clogging and the possibility of washouts. It also includes the inspection of revegetation on abandoned roads, and reseeding where necessary. As specified for construction activities above, end-haul and deposit all excavated material in safe bench or cove locations well above the high water level. Never deposit such material directly into flowing streams.

1. On all roads that outslope, cross drain them and remove all berms on the outside edge except those intentionally constructed for the protection of road grade fills.

2. Retain outslope road drainage by performing proper maintenance grading. This precludes both the undercutting of newly or partially stabilized cut slopes and the leaving of a berm (except for fill protection) along the outside edge of the road which might concentrate drainage on the road. Before spring runoff begins, remove all ice and snow berms created on winter haul roads.

3. Use extreme caution in the selection and application of herbicides for controlling brush encroachment along road edges. Do

not let any such chemicals drift or run off into streams to cause objectionable tastes or odors in the waters or to create adverse conditions for aquatic life or human consumption. Use mechanical equipment in preference to herbicides for control of roadside brush.

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APPENDIX A

INTERIM EFFLUENT GUIDANCE FOR NPDES PERMITS

Mining and Milling

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GENERAL EFFLUENT GUIDANCE FOR ALL INDUSTRIAL CATEGORIES

The following guidance on special technical considerations in the application of limitations, and on effluent limitations for specific parameters, is to be used as appropriate in writing permits for applications in all industrial categories.

General

The guidance documents were developed to cover, as specifically as possible, the identified industrial categories. The numbers previously developed and the information contained herein were meant to apply generally to the industrial category but more specifically to "major", "large", or more significant discharges. Additional information on other considerations (i.e., economic, age) will be forthcoming. This should not materially effect your priorities. However, should a problem arise that requires additional consideration, please contact the appropriate headquarters individual. You will find, as you probably already have, that the guidance does not lend itself to all situations involving "special" problems of age and economic impact, etc., for a given category.

pH

The normal range in which all discharges should fall is generally accepted to be between a pH of 6 and a pH of 9. Any discharge outside of this range should be well justified and should consider such things as the addition of total dissolved solids from neutralization and the buffering capacity of the receiving water. If the pH of the discharge

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is significantly different than the pH of the receiving water within the 6.0 to 9.0 range and the discharge is a significant portion of the receiving water, toxic effects due to pH fluctuations within this range can be shown. Therefore, it is imperative that the discharge be evaluated carefully even within the range of 6.0 to 9.0 (e.g., 7.0 $\pm$ 0.5).

Coliform

This is a significant parameter for mixtures of industrial wastewater and sewage and may be significant for certain industrial wastewaters alone. Because of the sewering of most plants, the absence of sewage should be established by dye test. If sewage is present, the following effluent limit should be imposed:

> "Organisms isolated in the fecal coliform test shall not exceed 1000 organisms per 100 ml."

Total Dissolved Solids

Total dissolved solids have not been limited in the individual guidance documents. There is technology available for the removal of total dissolved solids when receiving water quality so dictates.

Oil and Grease

Permit conditions for petroleum-based Oil and Grease, based on the Standard Methods (13th Edition, Method 137) are to reflect an achievable concentration of 10 mg/l as the basis for determining limitations.

This limitation should be imposed where appropriate across industrial categories. If petroleum-based oil and grease is not present in the characteristic discharge, the limitation may be eliminated. Oil and grease analysis may also be used to detect

oily materials of animal and vegetable origin. The limitation of oil and grease in these instances should be applied with caution. Vegetable or animal based oil and grease is generally less significant than petroleum based oil and grease at the same levels.

Toxicity

National standards for toxicity limitations via bioassay procedures have not been set. Certain States require bioassay procedures which will be incorporated in our discharge permits when those states include the requirement as part of certification under Section 401. A list of toxic substances and standards will be promulgated under Section 307 of the Act.

Heavy Metals

A general limitation of 1 mg/l maximum total dissolved heavy metals should not be imposed across the board. The figure is, however a good point of reference when extablishing limits for a discharge involving a number of dissolved heavy metals which could present a hazard to water quality due to synergistic toxic effects.

Utility Discharges, Thermal Energy

For practical purposes, thermal limitations are most significant when applied to once through non-process contact cooling water, and treated effluent. This includes both manufacturing industry and power generating industry.

The industrial effluent limitation guidance addresses "process wastewaters" only, which have come into intimate contact with raw material, products, byproducts, etc., and include all wastewaters containing significant amounts of non-thermal pollutants. Typically,

these streams require biological or physical treatment to reduce the content of specific constituents. When the resulting "treated effluent" contains thermal energy, additional considerations and limitations may be necessary.

Included in this definition of "process waterwaters" are cooling tower blowdown, boiler water blowdown, water treatment plant backwashings and once through process contact (e.g., barometric condenser) cooling water. However, limitations to be applied to constituents of these components of "process waters" are generally not contained in existing guidance.

Relative to pollutant reduction in utility water components of "process wastewaters", each case should be evaluated individually. Further definition of "best practicable control technology currently available" in this area has been undertaken by contract studies under Effluent Guidelines Division of Office of Water Programs.

The combination of cooling water and treated process water effluent prior to introduction into the receiving water is permissible. In instances where monitoring of the combined flows will not provide adequate information because of a concentration below a detectable limit, monitoring may be required prior to the combination of process flows and non-contact cooling water flows. Where once through non-contact cooling water is collected with process wastewaters in combined sewers, no allowance may be given that would condone the dilution of the plant raw waste load and result in a higher pollutant discharges allowance.

Once-through cooling water that does not come into contact with process material (shell and tube heat exchangers) discharging into segregated sewers may be excluded from the accounting of pollutants (excepting thermal) limited in the permit where source of water is the receiving stream. In such cases, thermal considerations should be applied taking into account applicable Water Quality Standards and using the guidance afforded in the Thermal Technical Manual forwarded earlier in draft form. Monitoring for possible contamination should be required, especially where saline cooling water is used. Due to the corrosive properties of saline water, corrosion products may be significant. The logic for excluding once through non-contact cooling water from pollutant limitation accounting is based upon net/gross considerations relative to influent constituents, and upon the "practicability" of treatment to reduce very low pollutant levels:

> Typically large quantities of water relative to process leakage result in concentrations not appreciably higher than supply water characteristics, and so low as to produce dubious analytical results.
>
> Unless a specific violation of Water Quality Standards results, such low concentrations would not ordinarily be expected to have a significant or adverse impact on the receiving water.
>
> In the absence of adverse impact (i.e., violation of Water Quality Standards) on the receiving water, the benefit of treating such large quantities of water (especially for net pollutant reduction) does not justify the cost.

Color

Color is generally an aesthetic problem. Where a specific problem is evident, limitations may be set on a case-by-case basis based upon receiving water quality.

Net and Gross

Generally a discharger is not responsible for pollutants entering with his water supply if he takes water from the same source into which he is discharging. If his source is other than the receiving stream, he is to be charged with the gross discharge.

Unless industry specifically requests application of net considerations in writing, or unless the difference between net and gross is of major significance to a discharger, the permit should be written on a gross basis with no stipulation for influent values. Where the differences between net and gross application of effluent guidance is of relatively minor significance but industry requests application of net values, the supply water waste loading should be stipulated based on presentation of existing data (i.e., adjust limitation accordingly and write permit in gross terms). Limitations that are established for materials that are normally expected to be "concentration controlled" (e.g., TSS and BOD) may not need total credit for influent levels (a well designed clarifier will generally produce a quality effluent - 20 mg/l ss - regardless of source of suspended solids). Where application of net values is of great significance to the dischargers, permit requirements for sampling the influent wasteloadings must be included.

Pollutants that are removed in the treatment of water in an industrial facility (e.g., silt removal, filter backwash) may not be returned to the receiving water. Once a pollutant is removed by the discharger it may not be reintroduced. In this situation net/gross considerations will be applied downstream of any pretreatment steps.

Disposal of Pollutants into Wells

If an applicant for a permit proposes to dispose of pollutants into wells as part of a program to meet the proposed terms of a permit, additional terms and conditions should be specified in the permit which either prohibit the proposed disposal or control the disposal so as to prevent pollution of ground and surface waters and to protect the public health and welfare. The Administrator's decision statement number five, February 6, 1973, "Environmental Protection Agency Policy on Subsurface Emplacement of Fluids by Well Injection" should be consulted and complied with.

Standard Conditions

The provided standard permit conditions will be included in each permit in the order and language given. Additional conditions necessary to meet state certification requirements will follow the standard special conditions in the permit. State requirements which exceed national requirements will generally be adopted for National Pollutant Discharge Elimination System permits written for discharges in the State. Please note, however, that only those State requirements included in the certification (Sec. 401 of the Act) must be adopted. Recommendations can be accepted for cause. In this manner, terms and conditions of dubious legal or technical validity, or that would tend to impede enforcement may possibly be screened out.

Limitations

Permits are to be written with limitations in terms of kilograms (pounds) of each pollutant per day excepting in certain industries (such as mining operations and utility discharges where wastewater generation is not related to production levels. The monthly operating average

effluent limitation, in kilograms (pounds) per day, should be calculated using the production basis multiplied by the appropriate effluent level as specified in the guidance. It is not our intent to specifically limit water use in the permit unless the flow is so high as to cause a scouring problem in the receiving water. Once a permit has been issued based on the use of effluent volume, production levels, and attainable abatement technology, the discharger may meet his requirement via any combination of effluent volume and concentration providing he does not violate water quality standards in so doing. If a discharger drastically reduces his water usage he may augment receiving water diffusion capacity to prevent localized toxic effects or take advantage of improved treatability to reduce pollutant discharge, at his option, within the life of the permit.

The basis for limitations shall be:

1. Monthly average, expressed in kilograms (pounds) of pollutant per day which is the total of each pollutant discharged in a calendar month divided by the number of days the production facility operated that month.

2. Daily maximum, expressed in kilograms (pounds) per day.

Maximum daily limitations have not been statistically established for all industrial categories. It is our intent that the discharge limitations developed from the guidance and other considerations be a monthly operating average and a daily maximum. Variations from this operating average will be monitored and used as a basis for judgment of the performance of the discharger and to establish statistical variability. When statistically reliable data is available, a maximum variation will be established on that basis. Until such is the case,

a general limitation for individual composite data shall be established that is no more than 3 times the average limitation (200% over) where water quality considerations do not prevail. Discharges may be limited singly or as a group or a combination of single discharges and groups or totally for the plant depending on the engineering judgment of the reviewer. It may be necessary to know the source of each discharge before making such a judgment. In any case, the total allowance of pollutant limitations should not exceed that calculated for the total plant production capability. Monitoring programs and compliance schedules should be consistent with approach chosen.

Production Figures to be Used in Permit Writing

A manufacturer should not be limited to less than full utilization of actual installed production capability. However, do not allow the purpose of effluent limitations to be circumvented by overstatements of production capability. The manufacturer is responsible for meeting the permit requirements without regard to seasonal variations in treatment efficiency, production levels, or product mix.

Therefore, the "production" figure can be either product or raw material as appropriate; shall be based on plant production capability whether by engineering evaluation or production history; and shall be based on the normal equipment operating schedule.

Where production units are separated, but utilize a common treatment facility, production will be evaluated for the production complex as a whole. One permit would be written for the production complex, covering all discharges to receiving water individually or combined as appropriate.

Where "production" is based on product, the total produced (including that shipped out of plant and/or placed in inventory) will be used. Similarly, where raw material (not including process chemicals) usage is the basis, the total processed will be used. In either case, assume a reasonable product mix which most fully utilized installed equipment.

For complex facilities, the capacity will be limited by the unit process which controls production, e.g., if an intermediate process can only supply 75 units to a downstream operation with a capability of 100 units, then the overall capability is 75 units unless purchased intermediate material is introduced. The determination, further, should be based on a normal operating schedule, e.g., shifts per week. There may be cases where increased production requirements are anticipated, and will be met by a heavier operating schedule (running the equipment more shifts per week). The heavier operating schedule may be used in defining plant capacity, but should be supported by market projections, production schedules, etc., that demonstrate the intent.

The production figure arrived at in this manner should not be an unreasonable deviation from historical actual production.

In any event, the manufacturer can apply for re-issuance of his permit based on increased production. As a rule-of-thumb, this should only be necessary when the contemplated production increase would cause overloading of treatment facilities, resulting in violation of the effluent limitations in the permit.

Level A and Level B

Minimum levels of treatment (B Level) were originally proposed in recognition of the economic hardship implicit in redirecting a pollution abatement program already under construction. However, setting specific minimum limitations for all industry raised the possibility of an implied benefit to dischargers only recently providing treatment. In addition, subsequent amplification of "best practicable control technology currently available" requires consideration of economic cost benefit relationships, as well as engineering aspects, non-water quality oriented environmental impact and others.

The primary mechanisms of relief will be reflected in compliance schedules terminating with achievement of Level A guidance by July 1, 1977. The most important consideration in using Level A and Level B is to remind the discharger that Level A values are to be met as a minimum requirement by July 1, 1977, by all dischargers.

Permit Duration

Permits may be issued for periods up to five years. If a discharger is expected to achieve A Levels by July 1, 1977, and he commits to a program to accomplish this, he will expect a permit of extended duration, i.e., five years. Short term permits, e.g., less than 3-5 years, should be issued only in those situations where there is a significant water quality problem that may not be resolved or where the technology for pollution abatement is not, in your opinion, sufficient, or where the discharger is not sure of the success of his planned program. In these instances the permit should be written to terminate 9 months after the conclusion of the compliance plan.

Staged Discharge

There may be instances where variability in receiving water flow (either regulated or natural causes) precludes discharge of even very highly treated wastewater due to stream quality considerations during low flow periods. In such instances, treated wastewater may be stored for discharge when receiving water considerations allow it. The discharge permit may therefore contain supplemental conditions permitting discharge in regulated amounts. In any case the total weight of individual pollutants so scheduled shall not exceed an appropriate limitation based on production capability.

Batch, Seasonal and Intermittent Operations

Batch, seasonal, and intermittent operations will be limited in the same terms as are continuous operations, i.e., a monthly operating average and a daily maximum, each expressed in pounds per day of individual pollutants. It may also, however, be necessary to set a limit on the rate of discharge in terms of pounds per hour in order to prevent violation of receiving water quality standards due to slug discharge.

The rationale is based upon the essential logic in the discussion of "production capability" plus a general condition in each permit requiring that the permittee operate the treatment facilities efficiently at all times. No attempt should be made to specify the days upon which a discharge is authorized.

Monitoring and Self Reporting

Separate guidance has been written for monitoring and self reporting. Generally the approach is that the permittee notify the regulatory agency in the event of violation of a daily maximum limitation (in which case, if immediate telephone notification is required, a 24-hour telephone number should be supplied), and that the permittee shall monitor and report routinely at such a frequency as to assure management and the regulatory agency that abatement programs are being implemented and the permit terms and conditions observed. Any discharge characteristics that are limited should be monitored, not necessarily all at the same frequency. Avoid limiting the same characteristic by more than one limitation; for instance, oxygen demand by BOD_5, COD and TOD.

Compliance Schedules

Proposed or tentative compliance schedules should be expressed in months elapsed from the effective date of the permit until the permit is issued at which time specific dates should by typed into the schedules. Interim limitations for "immediate" compliance (e.g., one month from effective date) should be imposed as necessary and desirable in order to either abate an "imminent hazard to public health or safety" or because it is feasible to abate the discharge immediately. Compliance with other limitations may require installation of waste treatment facilities, which would require additional implementation and compliance schedules.

It should be noted that a pollution abatement program for a complex industrial facility may involve installation of more than one treatment facility. Our interest is in the end result, not on the design or program

planning, excepting insofar as total compliance is achieved in a timely manner not to exceed July 1, 1977. Therefore, in a staged program, interim limitations may be imposed based upon completion of facets of an overall abatement program.

Treatment models described in the guidance are not intended to specify procedures or processes, but to illustrate the means by which the limitations may be met. Alternatives which will achieve the same end are acceptable.

Metric Units

All permits should be written in metric units (kilograms, meters, kiloliters) with equivalent English units (pounds, feet, gallons) in parentheses alongside.

Mining and Milling

Applicability

These instructions apply to Standard Industrial Classification Codes 1011, iron ores; 1021, copper ores; 1031, lead and zinc ores; 1042, lode gold; 1043, placer gold; 1044, silver ores; 1051, bauxite and other aluminum ores; 1062, manganese ores; 1064, tungsten ores; 1069, ferroalloy ores, except vanadium, not elsewhere classified; 1092, mercury ores; 1093, titanium ores; 1094, uranium, radium and vanadium ores; and 1099, metallic minerals (ores) not elsewhere classified.

Operations excluded

All subcategories not considered are excluded.

Application of limitations

This guidance should only be applied in very selected circumstances in the hard rock milling industry.

The effluent limitations are expressed only in concentrations. Due to the wide variations in ore types processed in this industry a pound-per-day limitation has been found to be impractical. If significant changes in production rates or changes in ore type processed are encountered this should be reported to the Regional Administrator.

A review of such changes will be necessary to determine the appropriateness of the limits used for preparation of the permit.

	Effluent Limitations Schedule A
Criteria	Recommended Limits
Suspended Solids	20 mg/l
Cyanide (Total)	When cyanide compounds are used in the milling process, effluent from the waste abatement system shall not exceed 0.02 mg/l.
Sulfate	The Regional Administrator or his designated representative shall establish an effluent limitation if beneficial downstream water uses are affected.
Radioactivity	Discharge concentration shall not exceed 1/10 of Bureau of Standards Handbook 69 values, or such standards as may be developed. RA-226 concentrations shall be as close to background as possible but in no case to exceed the addition of 1.0 picocurie per liter.
Iron (Dissolved)	0.5 mg/l
Manganese	0.1 mg/l

	Effluent Limitations Schedule B
Criteria	Recommended Limits
Suspended Solids	30 mg/l
Cyanide (Total)	When cyanide compounds are used in the milling process, effluent from the waste abatement system shall not exceed 0.03 mg/l.
Sulfate	The Regional Administrator or his designated representative shall establish an effluent limitation if beneficial downstreams water uses are affected.
Radioactivity	Discharge concentrations shall not exceed 1/5 of Bureau of Standards Handbook 69 values, or such standards as may be developed. RA-226 concentrations shall be as close to background as possible but in no case to exceed the addition of 3.0 picocurie per liter.

Criteria	Recommended Limits
Iron (Dissolved)	7.0 mg/l
Manganese	1.0 mg/l

Abatement Models

Mine Discharge

Mine discharge is commonly characterized by high acidity, and high metal and sulfate concentrations, resulting from the oxidation of sulfate minerals to form sulfuric acid and metal ions. Major reduction in the pollution caused by mine discharge can be achieved by procedures such as reducing the flow of the water to the mines, reducing the exposure of sulfide minerals to the atmosphere, or by flooding abandoned mine workings to reduce the rate of sulfide oxidation. Treatment of coal mine discharge usually takes the form of lime or limestone neutralization of free acidity, followed by sedimentation to remove the various metal hydroxides. Common treatment techniques are neutralization and sedimentation, with further metals removal by precipitation of the remaining metals as metal sulfide. This may, for example, be achieved by adding barium sulfide, resulting in the formation of a sludge which has excellent settling characteristics. The sludge can be smelted to recover the various metals. The reagent requirements are minor, as most of the metal ions are removed during the neutralization process.

Milling Discharge

Waste from milling consists of a water stream, frequently containing dissolved toxicants, acting as a carrier for ground mineral fragments. These latter usually include metal sulfides, subject to oxidation if

exposed to atmospheric conditions. Other materials of concern include reagents, such as cyanide, added to the milling circuit. The mill waste generally is alkaline.

Common treatment techniques utilized by the milling industry consist of discharging the slurry into a tailings pond, with sufficient detention to reduce the suspended-sediment concentration to approximately 20 mg/l. The clarified water is then either decanted to receiving streams or, in an increasing number of cases, recycled as mill process water. The latter procedure is preferred for environmental considerations. The treatment considered in the development of the attached limits, for discharge to streams, consists of primary sedimentation in a tailings pond, as is currently practiced throughout the milling industry. Following sedimentation, it is anticipated that the waste will be neutralized and treated for metals removal, as in the case of mine discharge, by sulfide precipitation.

Cyanide is frequently used in milling, both to dissolve gold and to prevent flotation of pyrite. Several other, less toxic, reagents are known to function equally as well as cyanide as a pyrite suppressant, and are recommended. Cyanide often decomposes during detention in a tailings pond. If the tailings pond decant contains high concentrations of cyanide, it is anticipated that the cyanide concentration will be reduced by the use of the alkali chlorination procedure.

Combined Discharge

Many operations produce both mine discharge and mill waste. Some improvement in water quality can be achieved by introducing the mine

discharge into the tailings pipe line. This results in partial neutralization of the acid mine discharge and alkaline mill waste.

Metals are removed through surface adsorption on the ground silica fragments. Where both wastes are present, it is anticipated that the two streams will be mixed, and treated as a single waste.

APPENDIX B

CHEMICAL CHARACTER OF MINE DRAINAGE FROM SOME INACTIVE MINES IN THE PACIFIC NORTHWEST

CHEMICAL CHARACTER OF MINE DRAINAGE

STATE IDAHO

ANALYSIS OF MINE WATER

Name of Mine: Adair
Location: On Manhattan Creek

T. 46 N R. 7 E Section 8
Subdivision _____ County Shoshone
Date Sampled 8/26/72 Flow 20 gpm
Drainage Basin Saint Joe

Temperature °C	11.6	
pH	7.1	
Conductivity	185	
Antimony, total		ug/l
Arsenic, total		ug/l
Cadmium, total	3	ug/l
Chromium, total		ug/l
Copper, total		ug/l
Iron, total	150	ug/l
Lead, total	5	ug/l
Manganese, total	9	ug/l
Mercury, total	.3	ug/l
Molybdenum, total		ug/l
Nickel, total		ug/l
Selenium, total		ug/l
Silver, total	1	ug/l
Zinc, total	10	ug/l

STATE IDAHO

ANALYSIS OF MINE WATER

Name of Mine: Alder Gulch
Location: East of Murray

T. 50 N R. 5 E Section 32
Subdivision _____ County Shoshone
Date Sampled 8/24/72 Flow Small
Drainage Basin Coeur d'Alene

Temperature °C	9.4	
pH	7.3	
Conductivity	300	
Antimony, total		ug/l
Arsenic, total		ug/l
Cadmium, total	6	ug/l
Chromium, total		ug/l
Copper, total	7	ug/l
Iron, total	1250	ug/l
Lead, total	45	ug/l
Manganese, total	50	ug/l
Mercury, total	.6	ug/l
Molybdenum, total		ug/l
Nickel, total		ug/l
Selenium, total		ug/l
Silver, total	1	ug/l
Zinc, total	510	ug/l

STATE IDAHO

ANALYSIS OF MINE WATER

Name of Mine: Bullion
Location: Near Wallace

T. 47 N R. 6 E Section 2
Subdivision _____ County Shoshone
Date Sampled 8/26/72 Flow Small
Drainage Basin Saint Joe

Temperature °C	16	
pH	7.4	
Conductivity	200	
Antimony, total		ug/l
Arsenic, total		ug/l
Cadmium, total	3	ug/l
Chromium, total		ug/l
Copper, total		ug/l
Iron, total	200	ug/l
Lead, total	5	ug/l
Manganese, total	8	ug/l
Mercury, total	.2	ug/l
Molybdenum, total		ug/l
Nickel, total		ug/l
Selenium, total		ug/l
Silver, total	1	ug/l
Zinc, total	10	ug/l

CHEMICAL CHARACTER OF MINE DRAINAGE

STATE IDAHO

ANALYSIS OF MINE WATER

Name of Mine California Gulch
Location Ninemile Creek

T. 49 R. 4 E Section 4
Subdivision S.E. 1/4 County Shoshone
Date Sampled 8/23/72 Flow Small
Drainage Basin Coeur d'Alene

Temperature °C	10.2	
pH	7.2	
Conductivity	235	
Antimony, total	7	ug/l
Arsenic, total		ug/l
Cadmium, total	3	ug/l
Chromium, total		ug/l
Copper, total	13	ug/l
Iron, total	1700	ug/l
Lead, total	50	ug/l
Manganese, total	83	ug/l
Mercury, total	.2	ug/l
Molybdenum, total		ug/l
Nickel, total		ug/l
Selenium, total		ug/l
Silver, total	1	ug/l
Zinc, total	70	ug/l

STATE IDAHO

ANALYSIS OF MINE WATER

Name of Mine Duncan Gulch
Location West of Murray

T. 49 N R. 4 E Section 2
Subdivision S.E. 1/4 County Shoshone
Date Sampled 8/23/72 Flow Small
Drainage Basin Coeur d'Alene

Temperature °C	10.9	
pH	7.1	
Conductivity	490	
Antimony, total	13	ug/l
Arsenic, total		ug/l
Cadmium, total	4	ug/l
Chromium, total		ug/l
Copper, total	4	ug/l
Iron, total	3300	ug/l
Lead, total	25	ug/l
Manganese, total	147	ug/l
Mercury, total	14	ug/l
Molybdenum, total		ug/l
Nickel, total		ug/l
Selenium, total		ug/l
Silver, total	1	ug/l
Zinc, total	80	ug/l

STATE IDAHO

ANALYSIS OF MINE WATER

Name of Mine Golconda
Location Along South Fork between and Mullan

T. 48 N R. 5 E Section 29
Subdivision _____ County Shoshone
Date Sampled 3/23/72 Flow 20 + gpm
Drainage Basin Coeur d'Alene

Temperature °C	12.5	
pH	6.8	
Conductivity	395	
Antimony, total	7	ug/l
Arsenic, total		ug/l
Cadmium, total	2	ug/l
Chromium, total		ug/l
Copper, total	6	ug/l
Iron, total	4250	ug/l
Lead, total	15	ug/l
Manganese, total	1200	ug/l
Mercury, total	.3	ug/l
Molybdenum, total		ug/l
Nickel, total		ug/l
Selenium, total		ug/l
Silver, total	1	ug/l
Zinc, total	20	ug/l

CHEMICAL CHARACTER OF MINE DRAINAGE

STATE IDAHO

ANALYSIS OF MINE WATER

Name of Mine: Monitor
Location: Near Wallace

T. 49 N R. 5 E Section 31
Subdivision: County: Shoshone
Date Sampled: 8/22/72 Flow: Small
Drainage Basin: Coeur d'Alene

Temperature °C	8.5	
pH	6.2	
Conductivity	720	
Antimony, total	14	ug/l
Arsenic, total		ug/l
Cadmium, total	34	ug/l
Chromium, total		ug/l
Copper, total	12	ug/l
Iron, total	550	ug/l
Lead, total	130	ug/l
Manganese, total	1010	ug/l
Mercury, total	.4	ug/l
Molybdenum, total		ug/l
Nickel, total		ug/l
Selenium, total		ug/l
Silver, total	1	ug/l
Zinc, total	11,200	ug/l

STATE IDAHO

ANALYSIS OF MINE WATER

Name of Mine: Murray
Location: Murray

T. 49 N R. 5 E Section 6
Subdivision: N.E. 1/4 County: Shoshone
Date Sampled: 8/24/72 Flow: Small
Drainage Basin: Coeur d'Alene

Temperature °C	10.6	
pH	6.8	
Conductivity	90	
Antimony, total		ug/l
Arsenic, total		ug/l
Cadmium, total	3	ug/l
Chromium, total		ug/l
Copper, total	9	ug/l
Iron, total	1300	ug/l
Lead, total	30	ug/l
Manganese, total	82	ug/l
Mercury, total	.3	ug/l
Molybdenum, total		ug/l
Nickel, total		ug/l
Selenium, total		ug/l
Silver, total	1	ug/l
Zinc, total	70	ug/l

STATE IDAHO

ANALYSIS OF MINE WATER

Name of Mine: Placer Gulch
Location: South of Wallace

T. 47 N R. 5 E Section 18
Subdivision: N.W. 1/4 County: Shoshone
Date Sampled: 8/27/72 Flow: 5 gpm
Drainage Basin: Coeur d'Alene

Temperature °C	14.4	
pH	7.1	
Conductivity	95	
Antimony, total	2	ug/l
Arsenic, total		ug/l
Cadmium, total	2	ug/l
Chromium, total		ug/l
Copper, total	5	ug/l
Iron, total	200	ug/l
Lead, total	10	ug/l
Manganese, total		ug/l
Mercury, total	.7	ug/l
Molybdenum, total		ug/l
Nickel, total		ug/l
Selenium, total		ug/l
Silver, total	1	ug/l
Zinc, total	10	ug/l

CHEMICAL CHARACTER OF MINE DRAINAGE

STATE IDAHO

ANALYSIS OF MINE WATER

Name of Mine: Silver Beaver
Location: On Deer Creek, North of Wallace
T. 49 N R. 4 E Section 21
Subdivision S.W. 1/4 County Shoshone
Date Sampled 8/23/72 Flow 10 gpm
Drainage Basin Coeur d'Alene

Temperature °C	9.5	
pH	6.8	
Conductivity	280	
Antimony, total	3	ug/l
Arsenic, total		ug/l
Cadmium, total	1	ug/l
Chromium, total		ug/l
Copper, total	4	ug/l
Iron, total		ug/l
Lead, total		ug/l
Manganese, total	5	ug/l
Mercury, total	.2	ug/l
Molybdenum, total		ug/l
Nickel, total		ug/l
Selenium, total		ug/l
Silver, total	1	ug/l
Zinc, total	60	ug/l

STATE IDAHO

ANALYSIS OF MINE WATER

Name of Mine: Snowstorm Peak
Location: East of Mullan
T. 48 N R. 6 E Section 30
Subdivision N.E. 1/4 County Shoshone
Date Sampled 8/22/72 Flow 30 gpm
Drainage Basin Coeur d'Alene

Temperature °C	7	
pH	7.1	
Conductivity	36	
Antimony, total	3	ug/l
Arsenic, total		ug/l
Cadmium, total	1	ug/l
Chromium, total		ug/l
Copper, total	246	ug/l
Iron, total		ug/l
Lead, total		ug/l
Manganese, total	22	ug/l
Mercury, total	.3	ug/l
Molybdenum, total		ug/l
Nickel, total		ug/l
Selenium, total		ug/l
Silver, total	1	ug/l
Zinc, total	10	ug/l

STATE IDAHO

ANALYSIS OF MINE WATER

Name of Mine: Sunset Peak
Location: North of Wallace
T. 49 N R. 5 E Section 28
Subdivision S.W. 1/4 County Shoshone
Date Sampled 8/23/72 Flow Small
Drainage Basin Coeur d'Alene

Temperature °C	5.1	
pH	6.1	
Conductivity	165	
Antimony, total	3	ug/l
Arsenic, total		ug/l
Cadmium, total	63	ug/l
Chromium, total		ug/l
Copper, total	12	ug/l
Iron, total		ug/l
Lead, total		ug/l
Manganese, total	240	ug/l
Mercury, total	.2	ug/l
Molybdenum, total		ug/l
Nickel, total		ug/l
Selenium, total		ug/l
Silver, total	1	ug/l
Zinc, total	10,200	ug/l

APPENDIX C

PHOTOGRAPHS DEPICTING TAILINGS PONDS AND WATER POLLUTION PROBLEMS RELATED TO MINING IN THE PACIFIC NORTHWEST

CHEMICAL CHARACTER OF MINE DRAINAGE

STATE WASHINGTON	STATE WASHINGTON	STATE
ANALYSIS OF MINE WATER	ANALYSIS OF MINE WATER	ANALYSIS OF MINE WATER
Name of Mine Holden	Name of Mine Triune	Name of Mine
Location Along Railroad Creek above Lake Chelan	Location Near Groville	Location
T. R. Section	T. 39 N R. 26 E Section 11	T. R. Section
Subdivision County Chelan	Subdivision County Okanogan	Subdivision County
Date Sampled 7/7/72 Flow 2 cfs	Date Sampled 8/2/72 Flow Small	Date Sampled Flow
Drainage Basin Lake Chelan	Drainage Basin Okanogan	Drainage Basin
Temperature °C	Temperature °C 12.3	Temperature °C
pH 4.5	pH 7.5	pH
Conductivity 720	Conductivity 790	Conductivity
Antimony, total ug/l	Antimony, total ug/l	Antimony, total ug/l
Arsenic, total 2 ug/l	Arsenic, total ug/l	Arsenic, total ug/l
Cadmium, total 43 ug/l	Cadmium, total 3 ug/l	Cadmium, total ug/l
Chromium, total 10 ug/l	Chromium, total ug/l	Chromium, total ug/l
Copper, total 2000 ug/l	Copper, total 9 ug/l	Copper, total ug/l
Iron, total 3000 ug/l	Iron, total 550 ug/l	Iron, total ug/l
Lead, total 65 ug/l	Lead, total 40 ug/l	Lead, total ug/l
Manganese, total 675 ug/l	Manganese, total 20 ug/l	Manganese, total ug/l
Mercury, total 25 ug/l	Mercury, total 1.2 ug/l	Mercury, total ug/l
Molybdenum, total ug/l	Molybdenum, total ug/l	Molybdenum, total ug/l
Nickel, total 10 ug/l	Nickel, total ug/l	Nickel, total ug/l
Selenium, total 5 ug/l	Selenium, total ug/l	Selenium, total ug/l
Silver, total 2 ug/l	Silver, total 2 ug/l	Silver, total ug/l
Zinc, total 16,400 ug/l	Zinc, total 20 ug/l	Zinc, total ug/l

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CHEMICAL CHARACTER OF MINE DRAINAGE

STATE WASHINGTON

ANALYSIS OF MINE WATER

Name of Mine Chloride Queen
Location Near Colville

T. 37 N R. 39 E Section 23
Subdivision _____ County Stevens
Date Sampled 8/9/72 Flow 3 gpm
Drainage Basin Colville

Temperature °C	10.9	
pH	7.3	
Conductivity	515	
Antimony, total	2	ug/l
Arsenic, total		ug/l
Cadmium, total	3	ug/l
Chromium, total		ug/l
Copper, total	7	ug/l
Iron, total	450	ug/l
Lead, total	30	ug/l
Manganese, total	36	ug/l
Mercury, total	1.0	ug/l
Molybdenum, total		ug/l
Nickel, total		ug/l
Selenium, total		ug/l
Silver, total	8	ug/l
Zinc, total	490	ug/l

STATE WASHINGTON

ANALYSIS OF MINE WATER

Name of Mine Eureka
Location _____

T. 37 N R. 39 E Section 3
Subdivision _____ County Stevens
Date Sampled 8/7/72 Flow 3 gpm
Drainage Basin Colville

Temperature °C	15.3	
pH	7.5	
Conductivity	610	
Antimony, total	2	ug/l
Arsenic, total		ug/l
Cadmium, total	4	ug/l
Chromium, total		ug/l
Copper, total	10	ug/l
Iron, total	300	ug/l
Lead, total	80	ug/l
Manganese, total	22	ug/l
Mercury, total	1.2	ug/l
Molybdenum, total		ug/l
Nickel, total		ug/l
Selenium, total		ug/l
Silver, total	5	ug/l
Zinc, total	160	ug/l

STATE WASHINGTON

ANALYSIS OF MINE WATER

Name of Mine Gold Hill
Location Near Darrington

T. 23 N R. 10 E Section 24
Subdivision _____ County _____
Date Sampled 8/ /72 Flow Small
Drainage Basin Stillaquamish

Temperature °C	12.8	
pH	6.8	
Conductivity	138	
Antimony, total	2	ug/l
Arsenic, total		ug/l
Cadmium, total	3	ug/l
Chromium, total		ug/l
Copper, total	110	ug/l
Iron, total	36,000	ug/l
Lead, total	85	ug/l
Manganese, total	610	ug/l
Mercury, total	1.4	ug/l
Molybdenum, total		ug/l
Nickel, total		ug/l
Selenium, total		ug/l
Silver, total	1	ug/l
Zinc, total	50	ug/l

CHEMICAL CHARACTER OF MINE DRAINAGE

STATE OREGON

ANALYSIS OF MINE WATER

Name of Mine Ashland

Location Near Ashland

T. 39 S R. 1 E Section 6

Subdivision _____ County Jackson

Date Sampled 6/25/72 Flow Small

Drainage Basin Rogue River

Temperature °C	11.4	
pH	8.3	
Conductivity	550	
Antimony, total		ug/l
Arsenic, total		ug/l
Cadmium, total	2	ug/l
Chromium, total	4	ug/l
Copper, total	10	ug/l
Iron, total	850	ug/l
Lead, total	10	ug/l
Manganese, total	38	ug/l
Mercury, total	1.4	ug/l
Molybdenum, total		ug/l
Nickel, total		ug/l
Selenium, total		ug/l
Silver, total	1	ug/l
Zinc, total	34	ug/l

STATE OREGON

ANALYSIS OF MINE WATER

Name of Mine Benton

Location Near Gahce

T. 33 S R. 8 W Section 27

Subdivision _____ County Josephine

Date Sampled 7/23/72 Flow 5 gpm

Drainage Basin Rogue River

Temperature °C	15	
pH	7.8	
Conductivity	510	
Antimony, total		ug/l
Arsenic, total		ug/l
Cadmium, total	1	ug/l
Chromium, total		ug/l
Copper, total	7	ug/l
Iron, total	290	ug/l
Lead, total	15	ug/l
Manganese, total	6	ug/l
Mercury, total	4.1	ug/l
Molybdenum, total		ug/l
Nickel, total		ug/l
Selenium, total		ug/l
Silver, total	2	ug/l
Zinc, total	53	ug/l

STATE OREGON

ANALYSIS OF MINE WATER

Name of Mine Blackjack

Location Near Granite

T. 9 S R. 35 E Section 14

Subdivision _____ County Grant

Date Sampled 7/19/72 Flow 30 gpm

Drainage Basin John Day

Temperature °C	10.3	
pH	2.8	
Conductivity	580	
Antimony, total		ug/l
Arsenic, total		ug/l
Cadmium, total	9	ug/l
Chromium, total		ug/l
Copper, total	1,250	ug/l
Iron, total	62,000	ug/l
Lead, total	15	ug/l
Manganese, total	4,400	ug/l
Mercury, total	2.0	ug/l
Molybdenum, total		ug/l
Nickel, total		ug/l
Selenium, total		ug/l
Silver, total	1	ug/l
Zinc, total	915	ug/l

CHEMICAL CHARACTER OF MINE DRAINAGE

STATE OREGON

ANALYSIS OF MINE WATER

Name of Mine: Ajax
Location: Near Granite

T. 8 S R. 35 1/2 E Section 22
Subdivision _____ County Grant
Date Sampled 7/19/72 Flow _____
Drainage Basin _____

Temperature °C	7.6	
pH	7.2	
Conductivity	850	
Antimony, total		ug/l
Arsenic, total		ug/l
Cadmium, total	4	ug/l
Chromium, total		ug/l
Copper, total	50	ug/l
Iron, total	18,000	ug/l
Lead, total	35	ug/l
Manganese, total	1,450	ug/l
Mercury, total	3.5	ug/l
Molybdenum, total		ug/l
Nickel, total		ug/l
Selenium, total		ug/l
Silver, total	2	ug/l
Zinc, total	1,060	ug/l

STATE OREGON

ANALYSIS OF MINE WATER

Name of Mine: Al Sarena
Location: Near Prospect

T. 31 S R. 2 E Section 29
Subdivision _____ County Jackson
Date Sampled 6/26/72 Flow _____
Drainage Basin Rouge River

Temperature °C	12	
pH	3.9	
Conductivity	330	
Antimony, total		ug/l
Arsenic, total		ug/l
Cadmium, total	8	ug/l
Chromium, total		ug/l
Copper, total	12	ug/l
Iron, total	8,250	ug/l
Lead, total	32	ug/l
Manganese, total	20,400	ug/l
Mercury, total	2.3	ug/l
Molybdenum, total		ug/l
Nickel, total		ug/l
Selenium, total		ug/l
Silver, total	1	ug/l
Zinc, total	4,500	ug/l

STATE OREGON

ANALYSIS OF MINE WATER

Name of Mine: Argonaut
Location: Near Bourne

T. 8 S R. 37 E Section 19
Subdivision _____ County Baker
Date Sampled 7/13/72 Flow 25 gpm
Drainage Basin _____

Temperature °C	9.1	
pH	7.1	
Conductivity	182	
Antimony, total		ug/l
Arsenic, total		ug/l
Cadmium, total	1	ug/l
Chromium, total		ug/l
Copper, total	17	ug/l
Iron, total	190	ug/l
Lead, total	15	ug/l
Manganese, total	26	ug/l
Mercury, total	2.0	ug/l
Molybdenum, total		ug/l
Nickel, total		ug/l
Selenium, total		ug/l
Silver, total	1	ug/l
Zinc, total	27	ug/l

CHEMICAL CHARACTER OF MINE DRAINAGE

STATE OREGON

ANALYSIS OF MINE WATER

Name of Mine: Buckeye
Location: Near Bourne

T. 8 S R. 37 E Section 27
Subdivision N.E. 1/4 County Baker
Date Sampled 7/14/72 Flow Small
Drainage Basin Powder

Temperature °C	12.3	
pH	6.6	
Conductivity	225	
Antimony, total		ug/l
Arsenic, total		ug/l
Cadmium, total	2	ug/l
Chromium, total		ug/l
Copper, total	10	ug/l
Iron, total	925	ug/l
Lead, total	15	ug/l
Manganese, total	325	ug/l
Mercury, total	1.3	ug/l
Molybdenum, total		ug/l
Nickel, total		ug/l
Selenium, total		ug/l
Silver, total	1	ug/l
Zinc, total	26	ug/l

STATE OREGON

ANALYSIS OF MINE WATER

Name of Mine: Buffalo
Location: Near Granite

T. 8 S R. 35 1/2 E Section 14
Subdivision County Grant
Date Sampled 7/19/72 Flow 3 gpm
Drainage Basin John Day

Temperature °C	10.3	
pH	6.5	
Conductivity	950	
Antimony, total		ug/l
Arsenic, total		ug/l
Cadmium, total	4	ug/l
Chromium, total		ug/l
Copper, total	10	ug/l
Iron, total	630	ug/l
Lead, total	30	ug/l
Manganese, total	1,075	ug/l
Mercury, total	1.5	ug/l
Molybdenum, total		ug/l
Nickel, total		ug/l
Selenium, total		ug/l
Silver, total	2	ug/l
Zinc, total	625	ug/l

STATE OREGON

ANALYSIS OF MINE WATER

Name of Mine: Cougar
Location: Near Granite

T. 8 S R. 35 1/2 E Section 27
Subdivision County Grant
Date Sampled 7/20/72 Flow Small
Drainage Basin John Day

Temperature °C	9.4	
pH	3.4	
Conductivity	1,716	
Antimony, total		ug/l
Arsenic, total		ug/l
Cadmium, total	6	ug/l
Chromium, total		ug/l
Copper, total	93	ug/l
Iron, total	425,000	ug/l
Lead, total	40	ug/l
Manganese, total	14,900	ug/l
Mercury, total	4.8	ug/l
Molybdenum, total		ug/l
Nickel, total		ug/l
Selenium, total		ug/l
Silver, total	3	ug/l
Zinc, total	1,205	ug/l

CHEMICAL CHARACTER OF MINE DRAINAGE

STATE OREGON

ANALYSIS OF MINE WATER

Name of Mine: Magnolia
Location: Near Granite

T. 8 S R. 35 1/2 E Section 22
Subdivision _____ County Grant
Date Sampled 7/19/72 Flow 2 gpm
Drainage Basin John Day

Temperature °C	8.1	
pH	7.1	
Conductivity	860	
Antimony, total		ug/l
Arsenic, total		ug/l
Cadmium, total	3	ug/l
Chromium, total		ug/l
Copper, total	23	ug/l
Iron, total	18,750	ug/l
Lead, total	30	ug/l
Manganese, total	500	ug/l
Mercury, total	2.1	ug/l
Molybdenum, total		ug/l
Nickel, total		ug/l
Selenium, total		ug/l
Silver, total	2	ug/l
Zinc, total	175	ug/l

STATE OREGON

ANALYSIS OF MINE WATER

Name of Mine: North Pole
Location: Near Bourne

T. 8 S R. 37 E Section 29
Subdivision _____ County Baker
Date Sampled _____ Flow 30 gpm
Drainage Basin Powder

Temperature °C	9.1	
pH	7.2	
Conductivity	850	
Antimony, total		ug/l
Arsenic, total		ug/l
Cadmium, total	2	ug/l
Chromium, total		ug/l
Copper, total	20	ug/l
Iron, total	110	ug/l
Lead, total	25	ug/l
Manganese, total	27	ug/l
Mercury, total	2.7	ug/l
Molybdenum, total		ug/l
Nickel, total		ug/l
Selenium, total		ug/l
Silver, total	1	ug/l
Zinc, total	68	ug/l

STATE OREGON

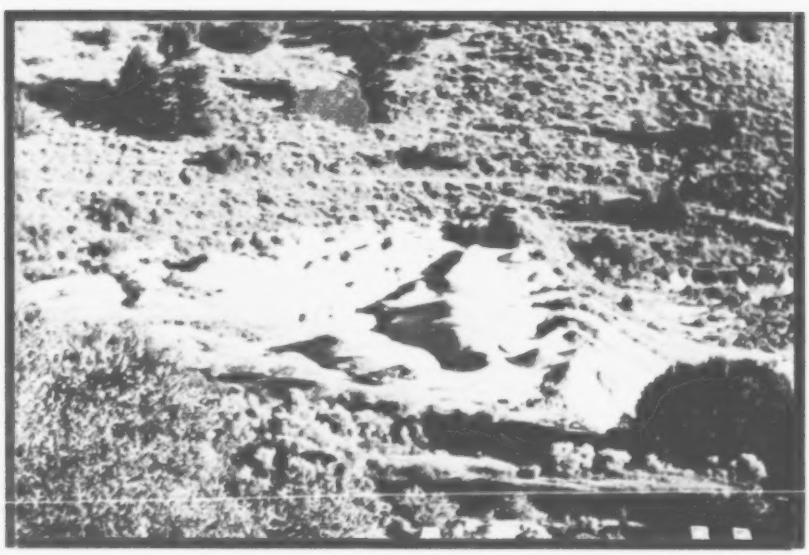
ANALYSIS OF MINE WATER

Name of Mine: Silver Peak
Location: Near Canyonville

T. 31 S R. 6 W Section 23
Subdivision _____ County _____
Date Sampled 6/27/72 Flow 3 gpm
Drainage Basin Rogue

Temperature °C	12	
pH	3.2	
Conductivity	650	
Antimony, total		ug/l
Arsenic, total		ug/l
Cadmium, total	65	ug/l
Chromium, total		ug/l
Copper, total	4,125	ug/l
Iron, total	42,000	ug/l
Lead, total	30	ug/l
Manganese, total	525	ug/l
Mercury, total	1.3	ug/l
Molybdenum, total		ug/l
Nickel, total		ug/l
Selenium, total		ug/l
Silver, total	1	ug/l
Zinc, total	25,000	ug/l

C 1 Erosion of an abandoned tailings pond in Idaho

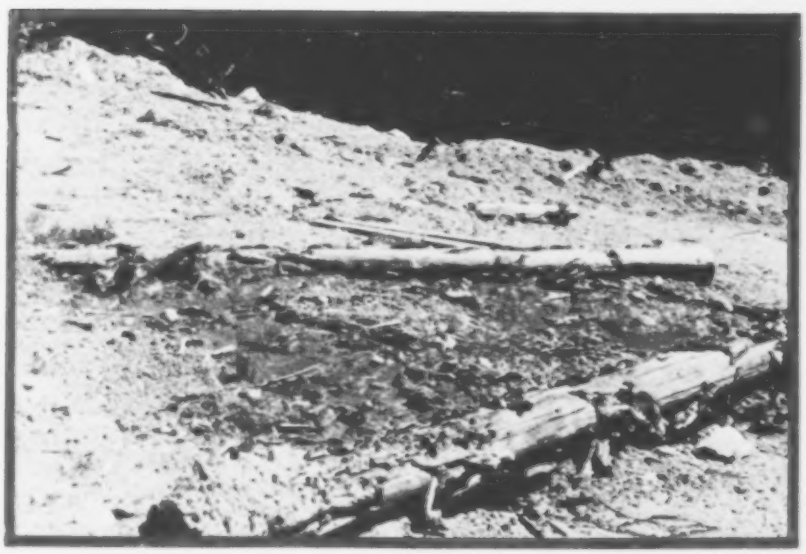


C 2 Erosion of an abandoned tailings pond in Oregon

C 3 Erosion of an abandoned tailings pond in Idaho

C 4 Erosion of an abandoned tailings pond at Holden, Washington

C 5 Tailings pond dike being raised

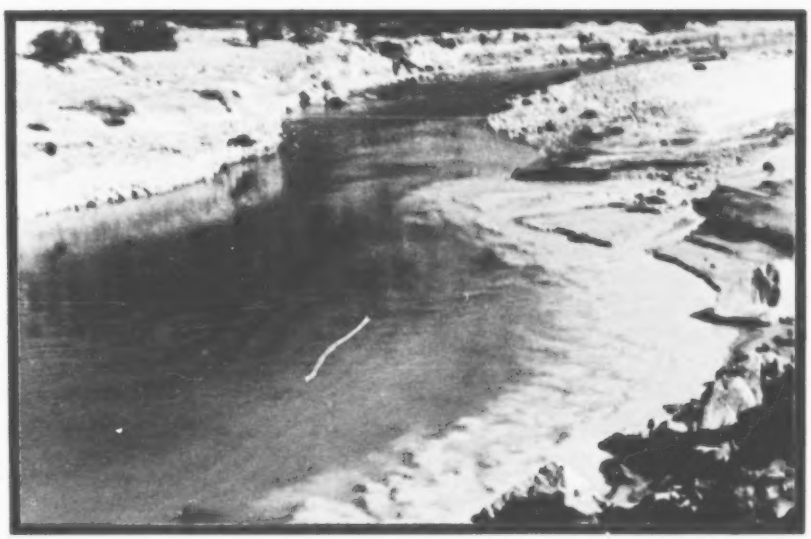


C 6 Mineralized water flowing from an abandoned drill hole

C 7 New tailings pond ready for filling

C 8 Tailings pond dike constructed of permeable alluvium

C 9 Stream barrier created by an abandoned open pit mine in Idaho

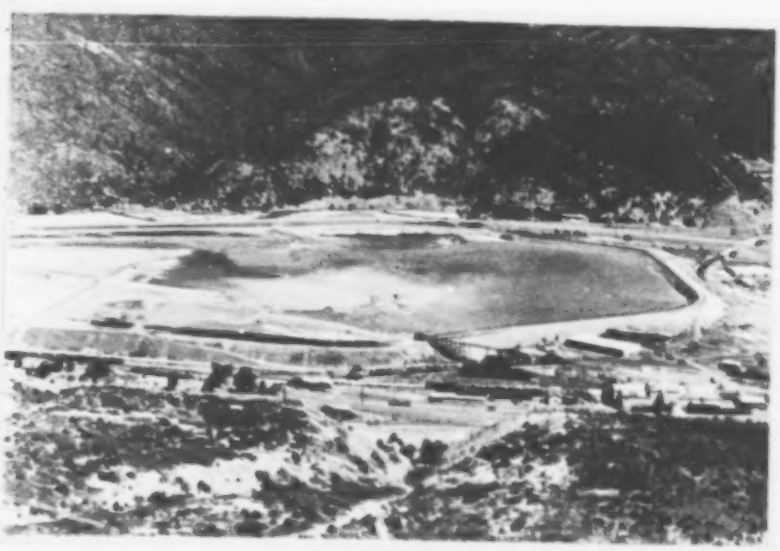


C 10 Turbid mine water being discharged to a stream in Idaho

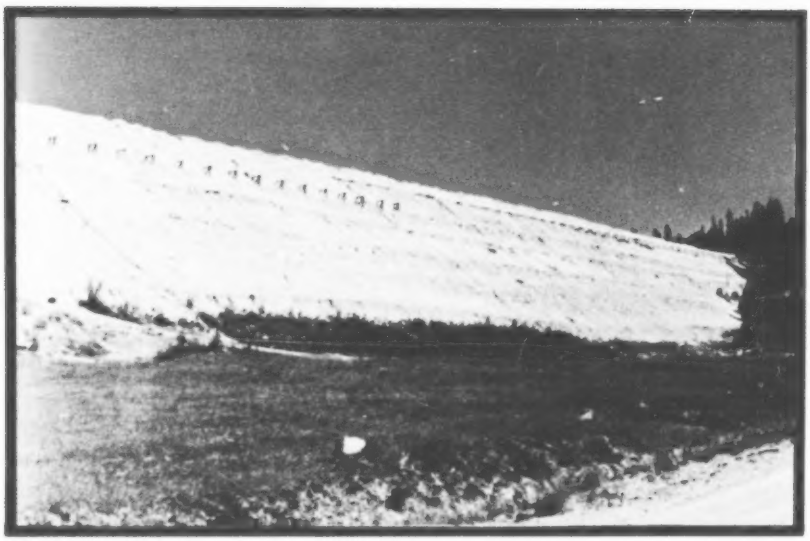
C 11 Waste drums and chemicals being exhumed by erosion of an abandoned tailings pond in Idaho

C 12 Acid mine water in an Oregon stream

C 13 The abandoned tailings pond at Holden, Washington showing the potential for stream erosion, ponded water contributing to leaching and the wind erosion problem



C 14 The central impoundment area of the Bunker Hill Company at Kellogg, Idaho. This is the largest tailings pond in the Pacific Northwest



C 15 Tailings pond dam constructed with tailings that is beginning to erode

C 16 Abandoned mine showing opening that would allow surface drainage to enter workings